Operations Research Center
United States Military Academy
West Point, New York 10996

SYSTEMS ENGINEERING FORCE XXI:
Experimental Analysis Integration and Systems Engineering Support to the Force XXI Design Effort

ORCEN Technical Report No. 95-6-1

Lieutenant H. Jay Brock
Lieutenant Colonel James E. Armstrong Jr., Ph.D.

January 1996

Directed by
Lieutenant Colonel James E. Armstrong Jr.
Associate Professor
Department of Systems Engineering

Approved by
Colonel James L. Kays
Professor and Head
Department of Systems Engineering

The Operations Research Center is supported by the Office of the Assistant Secretary of the Army for Financial Management

Operations Research Center
United States Military Academy
West Point, New York 10996

SYSTEMS ENGINEERING FORCE XXI:
Experimental Analysis Integration and Systems Engineering Support to the Force XXI Design Effort

ORCEN Technical Report No. 95-6-1

Lieutenant H. Jay Brock
Lieutenant Colonel James E. Armstrong Jr., Ph.D.

January 1996

Directed by
Lieutenant Colonel James E. Armstrong Jr.
Associate Professor
Department of Systems Engineering

Approved by
Colonel James L. Kays
Professor and Head
Department of Systems Engineering

The Operations Research Center is supported by the Assistant Secretary of the Army for Financial Management

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
Jan 1996

3. REPORT TYPE AND DATES COVERED
Technical Report

4. TITLE AND SUBTITLE
Systems Engineering Force XXI: Experimental Analysis Integration and Systems Engineering Support to the Force XXI design effort

5. FUNDING NUMBERS

6. AUTHOR(S)
LT. H. Jay Brock
LTC James E. Armstrong, Jr

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USMA Operations Research Center
West Point, New York 10996

8. PERFORMING ORGANIZATION REPORT NUMBER
95-6-1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A.
Approved for public Release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The purpose of this project was to provide systems engineering support to the Force XXI design and integration efforts of the Battle Labs Integration and Technology Directorate, Deputy Chief of Staff for Combat Developments (BLIT-CD) and the Future Doctrine Directorate, Deputy Chief of Staff for Doctrine ,(FUTURE-DOC) at Training and Doctrine Command Headquarters.

14. SUBJECT TERMS

FORCE XXI

15. NUMBER OF PAGES
80

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

Please direct comments on this report to:

LTC James E. Armstrong Jr.

Department of Systems Engineering
United States Military Academy
West Point, New York 10996-1779
VOICE: DSN 688-4698; COM (914) 938-4698 or 2700
FAX: DSN 688-5919 or 5665; COM (914) 938-5919
EMAIL: fj8305@usma8.usma.edu

This page intentionally not numbered.

ACKNOWLEDGMENTS

This project was sponsored by MG Larry G. Lehowitz and subsequently MG James J.Cravens Jr., the Deputy Chief of Staff for Combat Developments (DCSCD) and MG Boyd and subsequently MG Robert Scales Jr., the Deputy Chief of Staff for Doctrine (DCSDOC), Headquarters, US Army Training and Doctrine Command (TRADOC) at Ft. Monroe, Virginia. COL Hubbard and COL Klevecz, Director and Deputy Director (now Director) of the Battle Labs Integration and Technology (BLIT) Office, COL Mike Starry, Future Doctrine Office, and Ms Diane Schuetze, Chief of Modeling, Simulation and Automation, BLIT-CD all gave of their valuable time to contribute to this research effort. The research was supported by the Assistant Secretary of the Army for Financial Management.

Colonel James L. Kays, Professor and Head of the Department of Systems Engineering provided the in-house resources and guidance in coordinating and conducting the research. Mr. Paul Strassmann, an Adjunct Professor of Systems Engineering at the United States Military Academy (USMA), provided keen insights to the effort. Dr. Donald Barr, Professor USMA, reviewed a draft of the final written technical report and provided valuable comments. Major Flip deCamp helped with the formatting and figures in the final technical report. Major Cathy Brown helped construct the IDEF0 (activity model) diagrams that are in the report. All were motivated by the common cause to contribute to the future of the United States Army and I sincerely appreciate their sacrifice to add many hours to their already overloaded work schedules to help accomplish this research.

We offer these recommendations not as criticisms but as support to the many people in the Army team who are charged with building the Army's future. One of the challenges in undertaking the recommendations is how to accomplish some of them in a very resource constrained environment. Without exception, as I visited and worked with the various offices and labs, almost all of them were under-funded and over-worked as are the people in my organization. The costs in terms of personal sacrifices in the Army to help build its future in spite of overwhelming ongoing daily requirements should be a source of pride to all of us. Our best course of action in times like this, has to be not to

just work harder but also to work smarter. Hopefully, some of the ideas in this project have helped to do just that. My heartfelt thanks to all who have helped with this effort.

Executive Summary

The purpose of this project was to provide systems engineering support to the Force XXI design and integration efforts of the Battle Labs Integration and Technology Directorate, Deputy Chief of Staff for Combat Developments (BLIT-CD) and the Future Doctrine Directorate, Deputy Chief of Staff for Doctrine (FUTURE-DOC) at Training and Doctrine Command Headquarters. We display the six major objectives for this work in shaded boxes along with the major findings and recommendations summarized below each objective in clear text boxes.

To scope and bound Force XXI design efforts.

To scope the Force XXI design effort, we identified the **needs**, **objectives**, and **criteria** of Force XXI from a systems viewpoint. **Effective needs** are critical because *the definition of a successful design effort is meeting or exceeding the effective needs of the client or stakeholder group in a cost-effective, high-quality way.* So the effective needs must answer the question, "Why are we redesigning the Army to Force XXI?" Five statements drawn with some modification from TRADOC Pamphlet 525-5, in our opinion, answer this question. They are:

1. **To be trained and ready to win the first land battle with fewer, more economical but more capable forces.**

2. **To be rapidly tailorable, rapidly expansible, strategically deployable, and effectively employable as part of a joint and multinational team to achieve decisive results in future war and other operations in all environments.**

3. **To win simultaneous operations against foes of varying capabilities.**

4. **To find innovative ways to apply and combine current and new technologies, especially information technologies, for warfighting.**

5. **To win tactical battles quickly and decisively by maximizing information and combat power to dominate the battlespace.**

RECOMMENDATION 1: That the effective needs of the Force XXI design effort be clearly communicated to the Army to unite design efforts across organizations toward a common top-level goal. We propose the effective needs outlined above as a draft for senior decision makers to sharpen or revise.

To make Force XXI a reality, there are many lower level goals or objectives that should be pursued in a coordinated fashion to meet or exceed the effective needs of Force XXI. By parsing TRADOC Pamphlet 525-5, we identified more than seventy-five (75) objectives that Battle Labs and other Army organizations may want to pursue. We

structured these objectives into a conflict matrix of six objective trees or hierarchies to reflect tactical, operational, and strategic concerns across war and operations other than war. These objectives trees represent everything that the Army must make significant progress on to make Force XXI operations a reality.

> **RECOMMENDATION 2**: That Battle Labs and other Army organizations identify objectives and structure their objectives into objective trees, similar to the ones contained in this report, so they can have a coherent picture of everything they intend to accomplish to make significant progress toward Force XXI.

One of the findings from the Battle Lab visits was that they had difficulty articulating their objectives and understanding the objectives that they shared with other organizations. It is hard to make progress toward a goal when you don't know where you are going. Note that this does not conflict with the idea of a "journey not a destination." The kind of objectives that are outlined in this report are statements of intent that allow for many different alternatives and do not identify specific programs, systems, or technologies. Again, the objectives in this report are draft objectives, mostly extracted from TRADOC Pamphlet 525-5 and should be considered as illustrative examples. For the objectives to be worthwhile, each Battle Lab should create their own set of Force XXI objectives and then their should be a master integration effort of the objectives across the Battle Labs. The final structure of objectives should be integrated into subsequent revisions of Army doctrine so that organizations can pull together to accomplish them.

> **RECOMMENDATION 3**: That each Battle Lab develop meaningful, measurable criteria for their objectives. In this way, Battle Labs can determine how much progress they are making towards achieving their objectives.

The objectives trees will help Battle labs develop meaningful measures that they can use in experiments. Although higher level objectives may be difficult to measure, it should be possible to develop measurable criteria for each lower level objective. A weighted combination of lower level criteria can be used to measure a higher level objective.

> **RECOMMENDATION 4**: That Battle Labs should construct anti-objective trees which show objectives that counter the enemy's objectives. A sample anti-tree is in the report.

To bound a design means to identify the constraints, parameters, and variables of the problem. Constraints are the limits that are placed on the design solution and help to focus the design efforts toward feasible options. Parameters are elements of the design which can be changed to help define competing alternatives but they do not change once a particular alternative is in operation. For example, the number of tanks in a tank company or the number of soldiers in any infantry squad are design parameters of a force that can be changed to define different force options. Variables are important quantities that we

want to monitor as the design alternative actually operates or is simulated. For example, we want to know the cost of various force design options in terms of friendly casualties suffered in likely conflict scenarios. To make meaningful design progress, we need to know what can and what cannot be changed and how important variables are affected by different design choices. Here are some sample design constraints, parameters, and variables for Force XXI, some of which we extracted from TRADOC Pamphlet 525-5:

Constraints (Things we must adhere to as we design force options.)
- Keep a division base
- Maintain soldier focus
- Full dimensional force
- Change leader-to-led ratio
- Modular combat support and combat service support
- Smaller staffs
- Smaller units
- Mobile, multi-functional command posts
- Incorporate cybernetic or feedback mechanisms for adaptation and innovation
- And more

Parameters (Things we can change to create different options.)
- Number of command echelons in a division
- Number of control elements at each command echelon (e.g., tactical command posts)
- Number of staff elements at each command echelon
- Type of staff elements at each echelon
- Number of staff personnel in each element
- Number of units in each echelon of command
- Type of units in each echelon
- Number of systems (e.g., tank, Infantry Fighting Vehicle) in each unit
- Type of systems in each unit
- Number of soldiers in each crew or squad
- Type of soldiers in each crew or squad
- Type of units in the division base
- Size of units in the division base
- Number of functions performed at each echelon, unit, or element
- Type of function performed at each echelon, unit, or element.
- And more (such as Doctrine, Training, Leaders, Organization, Materiel, Soldiers)

Variables (Things we must monitor when we exercise or simulate force options)
- Amount of battlespace that can be dominated or controlled by the force
- Force recognition time (time that it takes for the force to recognize significant battlefield situations)
- Force response time (time that it takes for the force to respond to significant battlefield situations once recognition has occurred)

- Force tempo (the number of significant battlefield situations that the force can recognize and respond to in some specified unit of time)
- Number of enemy systems killed
- Number of friendly casualties
- Consumption rates (ammunition, fuel, food, expendable supplies)
- And many more

In addition to internal thinking about how the Army can change itself, we need some "out of the box" thinking about how the other services, that are part of the joint team, could change to make the overall team more efficient and effective. For example, are there functions or activities that take up a significant part of the Army's budget that should be offloaded to another service or are their better ways that other services could accomplish their functions and activities that would generate a savings that could be put to good use by the Army. Perhaps there are functions and activities that the Army performs for other agencies that should be done on a reimbursable basis. The systems point of view calls for examining not just redesigning the Army put also understanding how the Army should fit and work with all the other systems in its operating environment.

RECOMMENDATION 5: That Battle Labs, in their areas of expertise, help senior decision makers identify the design constraints that must be met and the design parameters that can be manipulated to create viable design options. Also, that Battle Labs determine how the variables of interest change for different design options across different operating environments and scenarios. This requires that Battle Labs have access to a robust modeling and simulation capability.

To help establish a coherent framework and consistent terminology for Force XXI

RECOMMENDATION 6: That the terms and definitions for Force XXI Operations doctrine be simplified as much as possible since doctrine needs to be soldier friendly. Currently there are many compound terms with lengthy definitions. Sample, simplified definitions of some key terms and concepts are in the report.

RECOMMENDATION 7: That a cybernetic or feedback control type paradigm of military conflict be incorporated into Army doctrine by using simple diagrams of sense-decide-act to help soldiers understand the relationship between information operations and combat operations. A sample diagram is in the report.

To help understand past Army Warfighting Experiments (AWEs), Advanced Technology Demonstrations (ATDs), and real operations in terms of their impact on designing Force XXI.

RECOMMENDATION 8: That the results of Army Warfighting Experiments (AWEs) be crosswalked with the main ideas in TRADOC Pamphlet 525-5 to identify trends that confirm or refute doctrinal ideas and to identify knowledge gaps where we need additional experimentation. A sample method to accomplish this with a crosswalk and results matrix is in the report.

RECOMMENDATION 9: That Battle Labs analyze recent real operations to understand shortcomings associated with their areas of oversight. A sample analysis of a recent operation is in the report. To accomplish this, the Battle Labs will need access to information about these operations, including perhaps real-time observers and qualified military operations analysts.

To help improve Battle Lab processes.

RECOMMENDATION 10: That Battle Labs develop a more detailed understanding of the battlefield activities they are trying to improve by constructing activity models (IDEF0) of their battlefield activities. A sample battlefield activity model for leading infantry battle complete with node trees and decomposition diagrams is in the report.

This does not imply that Battle Labs do not understand their battlefield activities. Rather, it means that the Battle Labs have difficulty explaining these activities to others and in communicating their reasons and justifying the value-added of particular technologies or other changes they want to make to the way they accomplish their battlefield activities.

RECOMMENDATION 11: That Battle Labs adopt and use a systemic, life-cycle process for the identification, assessment, and preliminary implementation of technology. This life-cycle has seven (7) important and related steps: **Scouting, Documentation, Assessment, Selection, Tracking, Disengaging, and Supporting**. More details on how this process works is in the report. To accomplish this, the Battle Labs will need "**Technology Scouts**" out immersed in the commercial sector who know the Army and can understand technology and its potential applications to warfighting.

RECOMMENDATION 12: That the Battle Labs develop a better understanding of battlefield and system architecture. This includes not just the physical and functional architecture but also the **operational architecture** for their area of concern-- how does it work when it is actually put into operation and where are the problems that arise during different modes of operation.

The recommendations from this work, if put into action, should help support the Battle Labs and other Army organizations and offices to make and evaluate progress on Force XXI. We shared interim briefings and emerging results from this effort with COLs Hubbard and Klevecz, and Ms Schuetze (BLIT-CD), MG Boyd and COL Starry (DCSDOC), and Dr. Phil Dickinson, Chair, Battle Labs Issues Study Group, Army Science Board.

Table of Contents

List of Figures

List of Tables

1.0 Project Objectives

We were tasked with the following six major objectives for this effort:

- To scope and bound Force XXI design efforts.
- To help establish a coherent framework and consistent terminology for Force XXI.
- To help understand past Army Warfighting Experiments (AWEs) and Advanced Technology Demonstrations (ATDs), and real operations in terms of their impact on designing Force XXI from a holistic perspective.
- To help guide future AWEs and ATDs.
- To help improve the Battle Labs processes.
- To help organize knowledge for Force XXI decision makers.

Achieving these goals will aid in moving from the current Army to the desired end state, meeting the effective needs of Force XXI. The clients for this effort are the Battle Lab Integration and Technology (BLIT) Office and the Future Doctrine Office at the US Army Training and Doctrine Command (TRADOC) Headquarters, Ft. Monroe, Virginia. The results of this work should support their efforts in helping the Battle Labs to make and evaluate their progress on Force XXI.

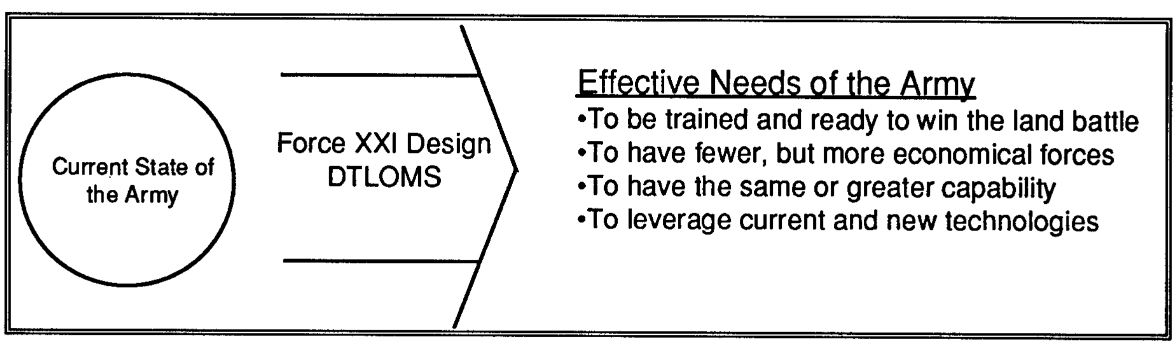


Figure 1.1 Designing Force XXI

2.0 Scoping Force XXI

To scope the Force XXI design effort, we identified the needs, objectives, and criteria of Force XXI as a system. Needs are conditions requiring relief or are the lack of something required, desired, or useful.[1] *Satisfying the effective needs of a client or stakeholder group in a cost-effective, high-quality way is the definition of a successful systems engineering design effort.* Effective needs, as opposed to primitive needs, are needs that have been analyzed and supported with evidence and convincing rationale. The effective needs for Force XXI, listed in the box below, were extracted from TRADOC Pamphlet 525-5, *Force XXI Operations*.

- To be trained and ready to win the first land battle with fewer, more economical but more capable forces.
- To be rapidly tailorable, rapidly expansible, strategically deployable, and effectively employable as part of a joint and multinational team to achieve decisive results in future war and operations other than war (OOTW) in all operational environments
- To win simultaneous operations against foes of varying capabilities.
- To find innovative ways to apply and combine current and new technologies, especially information technologies, for warfighting.
- To win tactical battles quickly and decisively by maximizing information and combat power to dominate the battlespace.

[1] Webster's Ninth New Collegiate Dictionary, 1990.

Effective needs are usually broad, top level goals that must be accomplished for the effort to be a success. Therefore, to get started on meaningful design work, it is typically necessary to define a set of lower level goals or objectives, that when completed, will satisfy the effective needs.

Before describing how we built the objectives trees, let us describe what they are and why they are useful. Objective trees are hierarchical structures that display the objectives of a design project from the top down. The reasons for using objectives trees to guide a design effort are listed in the bullets below.

- They represent everything the stakeholders want to accomplish with the design effort.
- They help to guide the development of criteria which can then be used to evaluate and compare alternative designs.
- They help to spark the ideation of activities which can then be used to generate alternatives.
- They help to identify trade-offs that must be carefully considered.
- They reveal hidden agendas and priorities of important stakeholders.
- They rationalize means to ends.

Although analyzing needs and constructing objectives are best accomplished with the willing participation of the stakeholders (Battle Labs), we did this work to illustrate what can be done and why it is useful to a large scale design effort. As part of this project, LTC Armstrong was an adjunct member of the Army Science Board Battle Labs Issues Study Group and was able to visit several of the labs as part of that group. To

construct the objectives trees found in Appendix A, B, and C, we first parsed TRADOC Pamphlet 525-5 and extracted a list of objectives from the document. We found most of the objectives we used in Chapter 3 of 525-5. The objectives did not seem to tie together very well until we divided them into their respective levels of warfare: strategic, operational, and tactical. Although 525-5 talks about how these levels of war are going to be compressed in time and space, we found it useful as an organizing principle to segregate objectives into these three time-compressed but interrelated categories. We also found it necessary to divide these three levels of goals into two categories: war and operations other than war (OOTW). We then constructed a tree for each level on each side for a total of six trees. This partition of objectives formed the conflict matrix shown in Table 2.1. See Appendices A and B for the objectives trees.

Each objective tree represents what 525-5 says the Army needs to accomplish for Force XXI operations. We think it would be a very useful exercise for the Battle Labs to layout a similar set of objectives trees and indicate which objectives they are working on and which objectives they share with other labs.

Table 2.1 Conflict Matrix

	WAR	OOTW
Strategic	X	X
Operational	X	X
Tactical	X	X

X= One Objectives Tree

We note that any specific conflict will probably involve several if not all of these entries in the matrix. It will be necessary to transition from one to another and we will probably be involved in conflict at multiple levels simultaneously. For example, if we are

successful against the enemy in a tactical war operation, it may be necessary to conduct peacekeeping operations (OOTW).

Once Battle Labs identify the objectives that they are working on, then they could explain what criteria they are using to measure their success in achieving their set of objectives. They could also explain how planned warfighting experiments and simulations relate to their objectives and what measurements will be taken during these events that will relate to the criteria they are using to measure their objectives.

Additionally, we looked at the idea of developing what we have termed "anti-trees" since war is a two-sided contest: friendly and enemy. For all six trees we developed, there are anti-trees that contain objectives which apply to countering the enemy. For every objective we are trying to accomplish, the enemy is trying to accomplish a similar objective. Therefore, we should develop specific objectives for hindering the enemy's ability to accomplish these objectives. For example, some of our trees contain the objective "To gain and share accurate and timely information." An anti-tree which applies to taking action against the enemy might have the objective "To hinder or disrupt the enemy's ability to gain and share accurate and timely information." This would allow Force XXI decision makers to look at both sides of war and OOTW and allocate resources appropriately. Although we developed only one anti-tree, anti-tactical war as shown in Appendix C, we think it would be useful to develop an anti-tree for each 'X' in the Conflict Matrix.

One of the important payoffs from objectives trees is that they help you develop criteria. Criteria measure success in attaining objectives and are very useful for evaluating

alternative designs. For example, in any experiments investigating Force XXI initiatives, you would expect to see data collection efforts oriented on quantifiable criteria that measure specific objectives. The idea is to use lower level objectives to help suggest criteria or objectives measures. As an example of this, we defined the criteria (with units in parentheses), shown in Table 2.2, as possible ways to measure some of the Force XXI objectives.

Table 2.2 Possible Force XXI Success Criteria

Objective	Criteria (with Units)
To maximize the warning time for commitments	Warning time (in Days)
To maximize the number of simultaneous operations controlled at each level	Number of simultaneous operations (number)
To maximize the number of nearly simultaneous attacks throughout the battlespace	Number of nearly simultaneous attacks in one hour (number)
To maximize stand-off ranges for major weapons systems	Percent increase in stand-off range (%)

3.0 Bounding Force XXI

To bound Force XXI, we identified the parameters, variables, and constraints of the system. Parameters are characteristics which do not change once the system is in operation. Examples of parameters are the number and type of units in place once Force XXI is implemented and the command and control structure for these units. Once Fore XXI is put into place, these parameters are not likely to change much. In fact, the values to which these parameters are set will largely define the various alternative designs for Force XXI and determine the relative capabilities that each design can achieve.

A variable is something that changes as the system (Force XXI) operates. There are many variables that change as a force operates: ammunition on hand, soldiers present for duty, and the number of operational combat vehicles are a few examples. Understanding how these variables are likely to change due to different Force XXI designs is important especially when considering force employment and sustainment issues. TRADOC Pamphlet 525-5 addresses some of these issues but without much resolution or definitions of success.

Constraints are the boundary conditions within which the system must operate. Although some of these constraints may not be binding, which means that Army leaders may decide some may have to be violated, we have identified some important Force XXI constraints from 525-5 that will impact the design of the Army for the 21st century:

- Keep a Division Base
- Maintain Soldier Focus
- Full Dimensional Force

- Must Change Leader-to-Led Ratio
- Modular Combat Support (CS) and Combat Service Support (CSS)
- Smaller Staffs
- Mobile, Multi-Functional Command Posts
- Incorporate Cybernetic or Feedback Mechanisms

4.0 Terminology and Paradigms

Since doctrine provides a common language as a basis for communication and understanding, we think it is important to help establish a consistent terminology and common understanding for Force XXI.

4.1 Force XXI Terms

To this end, we looked at the glossary and text of 525-5. We attempted to define any terms that we did not find in the glossary. We found that there are many different terms used that are not well defined or widely understood although they may be well understood by key decision makers. In fairness to the writers of 525-5, their aim was to think into the future, so you would expect terms and concepts that are still emerging and are not well-defined to be integral to the document's purpose. It is essential that doctrine has a consistent terminology so that a common language exists for understanding and discussing concepts of operation, tactics, techniques, and procedures. Therefore, more work needs to be done to carefully define Force XXI terms, explain what they mean, and explain how they relate to each other in the context of Force XXI operations. The table below is a list of some key terms with possible definitions.

Table 4.1 Sample Force XXI Terms and Definitions

battle	Combat between armed forces	LTC Armstrong
dynamic	Cause of change over time in a system, process, or operation	LTC Armstrong
battle dynamic	A cause of change over time in combat between armed forces. In 525-5, a significant area of change from current operations to Force XXI operations. Five major interrelated battle dynamics are battle command, battlespace, depth and simultaneous attack, early entry, and combat service support.	Modified FM 525-5

space	The infinite dimension of the three dimensional field.	Webster
battlespace	The depth, breadth, and height within which the conflict or combat between armed forces occurs. The dimensions of battlespace are determined by the maximum capabilities of friendly and enemy forces to acquire and dominate each other by fires, maneuver, and information.	Modified 525-5
commitments	Engagements to which US military forces will be bound to accomplish missions in both war and OOTW.	Modified 525-5
connectivity	The quality or state of being joined or linked together with other force elements so that the elements can exchange information and coordinate their operations. Often used in the context of having the ability to coordinate and perform joint, interagency, or multinational operations via communications links.	LTC Armstrong
expansible	Capable of being increased in number, volume, scope, or extent especially the battlespace that the force occupies and dominates after expansion.	Modified Webster
interchangeable	The ability to substitute each (of two) force elements or components for each other.	Modified Webster
tailorable	The ability to adapt, change, or organize force elements to suit a special need or purpose such as a particular situation defined by the mission, enemy, terrain, troops, and time available (METT-T).	LTC Armstrong
modularity	A force design methodology that establishes a means to provide interchangeable, expandable, and tailorable force elements.	525-5
operation	A set of synchronized actions planned and executed to achieve an objective.	LTC Armstrong
information	Communication or reception of knowledge that increases the ability to understand and deal with current and future situations, especially new or difficult situations.	LTC Armstrong
information operation	A set of synchronized information actions planned and executed to achieve or help achieve an objective. In 525-5, continuous combined arms operations that enable,	LTC Armstrong and 525-5

	enhance, and protect the commander's decision cycle and execution while influencing an opponent's; operations are accomplished through effective intelligence, command and control, and command and control warfare operations, supported by all available information systems; battle command information operations are conducted across the full range of military operations.	
process	A series of interdependent steps that result in a significant change to some object or set of things.	LTC Armstrong
system	A set of components or elements that work together for a specific purpose.	LTC Armstrong
technology	The organization and application of scientific and engineering knowledge to enhance some human activity (such as warfare) or to extend some natural process by manmade means.	LTC Armstrong
technology trend	The general direction that the enhancement of some human activity takes over time.	LTC Armstrong
simultaneous	Happening, existing or done at the same time or within some specified timeframe.	Adapted from Webster
tempo	The rate or pace of some activity.	Webster

4.2 A Force XXI Paradigm

A paradigm is an outstandingly clear example or simple model that helps people understand and think about reality better. So, as we write doctrine and train leaders and soldiers, we need to ask ourselves what is the clear example or simple model that leaders and soldiers are using in their minds to understand and think about Force XXI and future conflict. To be useful, a paradigm must help us understand and explain reality. It must help us get answers to important questions about why we are making changes to the way

the force is designed and why we are making changes to the way we operate the force. We might start by asking what is the old paradigm we were all using and is it still appropriate for the future?

The current paradigm is the relative combat power model developed by BG (ret.) Huba Wass de Czege.[2] According to doctrine experts, it has served as the basis for all versions of FM 100-5 since 1982.[3] His model states that the outcome of battle depends on the difference in the combat power of the antagonists. Combat power, in his model, is a function of what leaders do with the firepower, maneuver, and protection capabilities of their units. He stresses the word "relative" because it is the combat power effects that are generated at the decisive place and time on the battlefield that count not just the potential for combat power in general. This means that you can fight outnumbered and win if you are smarter than your enemy. His model also recognizes that warfare is a two-sided contest by including a degradation factor to combat power that represents one side's effort to minimize the other side's combat capabilities and vice versa. Is this model good enough or do we need to update it for the information age Army? If so, then how?

One way to update the relative combat power for the information age is to add information as another main variable or effect to the model. In this updated model, combat power is now a function of what leaders do with the firepower, maneuver, protection, and **information** capabilities of their units. Of course, each of the variables in the combat power model is a function of many other important variables. BG Wass de Czege does an excellent job of detailing all of these complexities. In fact, there are many

---

[2] *Understanding and Developing Combat Power* by Huba Wass de Czege, February 10, 1984.
[3] Memorandum by Colonel Mike Starry, Subject: Analytic Foundations for the "Long View," September 7, 1994.

information variables embedded in many of his detailed explanations of firepower, maneuver, and protection. A challenge for Force XXI is to organize and understand the application of information effects as a way of generating combat power to the same level of detail as the other terms in the combat power model. For instance, there are at least two more levels of abstraction or layers of variables in the original model (18 more specific variables at the second level and 64 at the third or lowest level). Here is a the relative combat power model updated for information showing the first level of five basic variables.

$$\mathbf{L_f (F_f + M_f + P_f + I_f - D_e) \;-\; L_e (F_e + M_e + P_e + I_e - D_f) \;=\; The\ Outcome\ of\ Battle}$$

Figure 4.1 Combat Power Model Equation Updated for the Information Age

where

L_f - friendly leadership effect	L_e - enemy leadership effect
F_f - friendly firepower effect	F_e - enemy firepower effect
M_f - friendly maneuver effect	M_e - enemy maneuver effect
P_f - friendly protection effect	P_e - enemy protection effect
I_f - friendly information effect	I_e - enemy information effect
D_e - enemy degrading of effects	D_f - friendly degrading of effects

One of the advantages of the combat power model was that it included both qualitative and quantitative aspects. That is, it was not just a subjective model that claimed warfare was only an art nor was it only an objective model that claimed warfare

was just a science. It allowed for the judicious blend of both perspectives. Still, we might want to examine one more aspect of the combat power model that appears to limit its application in the information age even after adding the information term. This limiting aspect concerns the basic assumptions of the model. What were these?

As you might expect, the original combat power model assumed the continued preeminent concern of the Soviet Union. Therefore, the central purpose of the combat power model was to turn combat potential into combat power in such a way as to defeat Soviet forces in combat *action*. While the purpose of combat action is still of great importance, we need to also consider the other possibilities that exist in the information age. For example, consider the diagram in Figure 7.2 below which shows the basic command and control process for two opposing forces.[4] The traditional combat power model focuses on the primary possibility of direct combat where the blue forces and red forces are engaged against each other in combat actions. This traditional possibility is shown in the diagram as the double headed arrow labeled combat. New information age technologies now make the other possibilities shown by the psychological operations arrow and the information operation arrows important to consider. The diagram shows that we can potentially put effects now, better than ever perhaps, on the goals, decision processes, and the sensor or information gathering capabilities of our enemies. The possibilities become even more interesting when you examine a third party to the conflict

[4] Adapted from a diagram in William B. Cunningham's briefing "A Proposed Approach to Understanding and Modeling Information Operations," January 12, 1996. The author, J. E. Armstrong, presented similar ideas in the context of command and control systems in 1987 in a technical report "Decision Making Models for Command and Control." This general sense-decide-act process, or observe-decide-act cycle, has been called the command-and-control process model by Lawson originally and then also the commander's decision cycle, so perhaps this paradigm is not new but also needs to be updated for the information age.

such as a peacekeeper who now can put effects on both antagonists (as well as receive effects from both). A complete discussion of this paradigm for thinking about conflict is beyond the scope of this report but it does illustrate the need for considering the kind of thinking or analytical framework we want Army leaders to use to understand warfare in the 21st century.

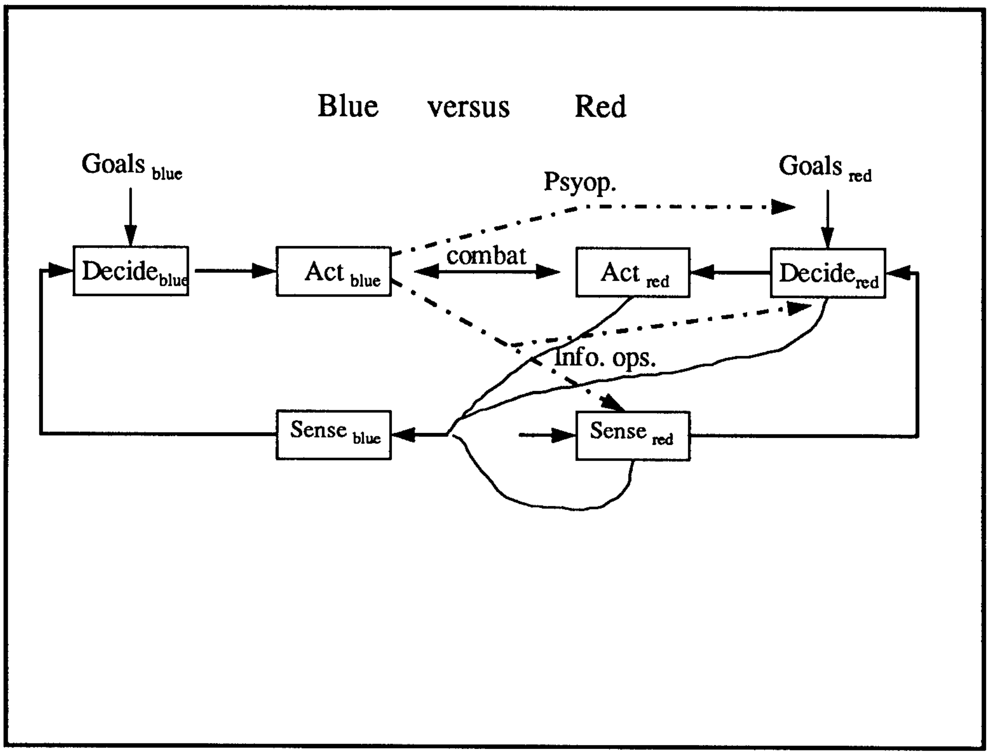


Figure 4.2 New Paradigm for 21st Century Conflict

5.0 Learning from Past and Future AWEs

To help understand past and future Army Warfighting Experiments (AWEs), we developed a crosswalk of 525-5 main ideas and Battle Lab experiments (AWEs). By rating each experiment for its success in achieving a main idea, analysts will be able to identify gaps and trends in performance for senior decision makers.

+	Confirm
0	No evidence
-	Contradict

We suggest using simple entries in a crosswalk or interaction matrix like the one shown at the right. An entry of '-' means that the experiment's results seemed to contradict the main idea outlined in 525-5. An entry of '0' means that the experiment's results did not seem to provide any information to either confirm or contradict the main idea. When the results of an experiment confirm a main idea described in 525-5, then an entry of '+' is made. Crosswalking results from experiments to the main ideas or premises in 525-5 provides a way to better understand past experiments and also a way to guide the design of future experiments.

A positive trend, evidenced by a row of many '+'s, indicates that the main idea in 525-5 appears to be confirmed by several warfighting experiments. A gap, evidenced by a row of many '0's, means that the main idea was not tested by the experiment and that perhaps the idea should be considered for future experimentation. A negative trend, evidenced by a row of '-'s, indicates that the main idea may not be a great idea; the decision makers will have to reexamine the idea. The table below shows what a crosswalk of 525-5 main ideas and AWEs might look like. Appendix I demonstrates a framework

for accomplishing this task that relates individual AWEs with their corresponding hypotheses, results, and insights to this crosswalk matrix.

Table 5.2 Sample Crosswalk Matrix of 525-5 Main Ideas with AWEs

Main Ideas 525-5	*AWE 94-4*	*AWE 95-6*	------------	*AWE N*	*Summary*
Main Idea 1	+	+	---------	+	Confirm
Main Idea 2	0	0	---------	0	Gap
---------	----------	----------	---------	----------	---------
Main Idea N	-	-	----------	-	Contradict

Each entry in the crosswalk or interaction matrix above has to be supported by additional information. We recommend a supporting table like the one shown below for each AWE that list the hypotheses, results and insights for each experiment. These summaries of AWE results should be put together by an analytical agency such as TRADOC Analysis Command in coordination with the appropriate Battle Lab.

Table 5.3 Sample Supporting AWE Information Table for Crosswalk Matrix

Hypotheses		**Task Force XXI**	
If . . .	**Then . . .**	**Results**	**Insights**
Information-age battle command capabilities and connectivity exists across all battlefield operating systems and functions within and to a brigade task force,	Significant enhancements in lethality, survivability, and tempo will be achieved.	TBD	TBD

6.0 Improving Battle Lab Processes

Previous sections in this report discuss how Battle labs may want to use objectives trees to chart their course and measure their progress and how they can crosswalk results from AWEs with future doctrine to better understand past experiments and to better plan future experiments. This section discusses three related areas where Battle labs may want to look at improving their processes or way of doing business: technology, process reengineering or activity modeling, and architecture.

6.1 Technology

Since one of the effective needs of Force XXI is "to find innovative ways to apply and combine current and new technologies [especially information technologies] for warfighting," it is important that Battle labs have an organized and understandable approach to their technology efforts. This means that Battle labs need to be able to explain and justify their technology efforts and initiatives, so several viewpoints on defining technology, and information technology in particular, follow.

Technology is the organization and application of scientific and engineering knowledge to enhance some human activity such as warfare. Technology often extends or improves some human or natural process, such as the extension of a soldier's natural night vision abilities by night vision goggles. In other words, technology helps people do things. A **technology trend** is the general direction that the enhancement of some human activity by science takes over time. To be a significant trend, there must be some order of magnitude of enhancement. For example, some activity must be made faster, easier, or better by severalfold or more. Sometimes a significant trend in technology is capable of

transforming some human activity -- the activity can now be done in an entirely new and different way.

Information technology is the application of scientific and engineering knowledge to help people work with data, information, and knowledge. A more technical definition of information technology is that it is the acquisition, storage, processing, transmission, and representation of vocal, pictorial, textual, and numeric information by microelectronics, computers, and telecommunication technologies (Armstrong, 1994, pp. 68-71). Important questions for the Battle labs to answer are what significant trends and developments in technology in general, and information technology in particular, should be leveraged to improve the activities and capabilities that are important to their battlefield areas of concern? To accomplish this task, Battle Labs need a logical and understandable process for examining technology innovation.

Battle Labs should consider adopting **a systematic, life-cycle process for the identification, assessment, and preliminary implementation of technology**. This systems approach has seven (7) important and related steps (Sage, 1992, p. 104).

- **Scouting**
- **Documentation**
- **Assessment**
- **Selection**
- **Tracking**
- **Disengaging**
- **Supporting**

Scouting involves the identification of requirements for candidate technologies. To accomplish this, the Battle Labs need "**technology scouts**" out in the commercial sector, where the rapid advances in information technology are occurring, who can know the Army and the Battle Labs functional areas and can also understand and speak in technical terms. **Documentation** involves capturing information about the warfighting need for, and the feasibility of, the technologies identified by scouting. **Assessment** is a formal evaluation of the technologies to collect information which can be used to make a selection.

Selection is the decision to allocate scarce resources for initial development and implementation of chosen technologies for specific purposes. **Tracking** is the monitoring of the progress of the technical development of the technology and its implementation. **Disengaging** is the step in the process which realizes that technology ventures are often risky and need to be abandoned when risk exceeds certain limits. Also, when technology projects have been successfully transferred, resources should be directed at new projects. **Supporting** is the final step in the process, where the technology is successfully transferred to another responsible element in the organization, or where some meaningful operational implementation is achieved. The next section describes a way to help Battle labs understand where and how they can apply technological advances to the battlefield activities that they oversee.

6.2 Reengineering Processes and Activity Modeling

To help improve Battle Lab processes and organize knowledge for Force XXI decision makers about streamlining battlefield activities and applying new technologies to

warfighting, we demonstrate the activity modeling technique IDEF0 (pronounced eye-deaf-zero). An activity model is a hierarchical structure used to describe activities and their relationships. A completed activity model graphically depicts the specific steps, operations, and information needed to perform an activity. Activity modeling could be very beneficial to the Battle Labs in two ways: to study battlefield activities and to examine their own internal processes. Using activity models in these two areas would help to:

- Identify redundant battlefield activities
- Find ways to eliminate unnecessary actions and streamline processes
- Find opportunities for inserting technology into battlefield activities
- Evaluate activities in terms of their value-added and costs

It is important to understand that an activity is defined as "the transformation of inputs into outputs performed by mechanisms under the constraints set by controls" and that the diagrams are set up in the Input-Control-Output- Mechanism (ICOM) format shown in Figure 6.1.

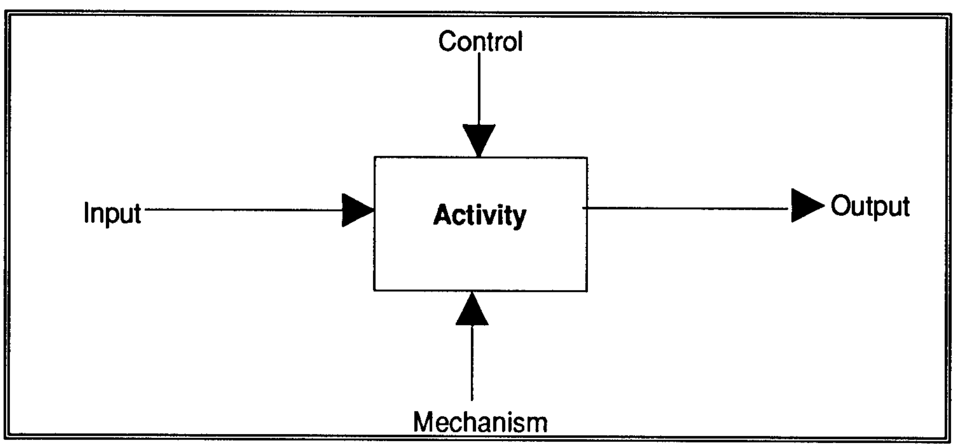


Figure 6.1 ICOM Diagram

Shown below is our activity model of leading battle at the company level. First, we subdivided the activity of leading battle into three steps using a node tree diagram.

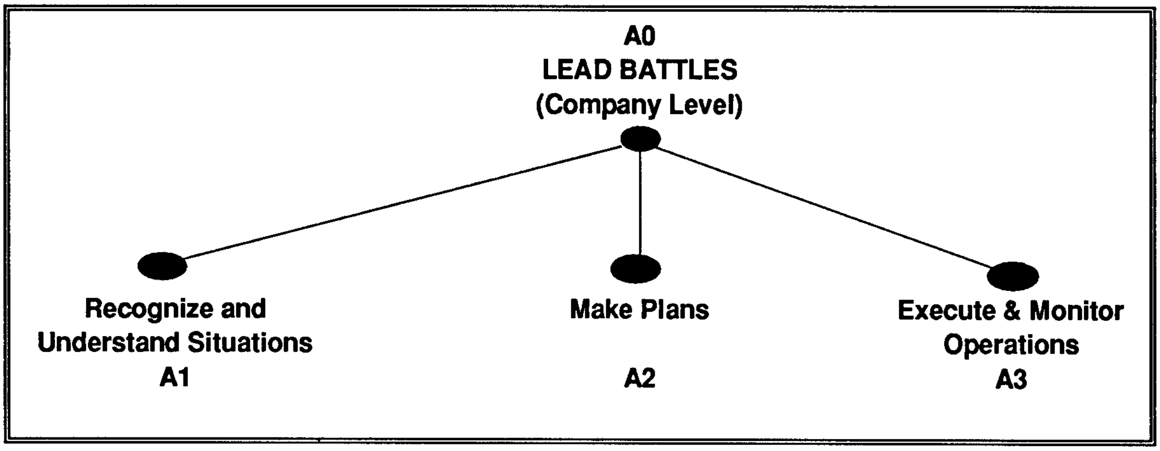


Figure 6.2 Node Tree Diagram of Lead Battle

We then broke the three steps of leading battle down into individual steps. These trees can be found in Appendix C. After making the node trees, we constructed the decomposition diagrams. For each branch of a node tree, there is a corresponding decomposition diagram. Figure 6.3 is a decomposition diagram for the node tree in Figure 6.2. Note that each decomposition diagram is labeled with an activity designation (A0), the name of the activity (Lead Battle), and the viewpoint from which the activity is constructed (Company Commander). The diagram contains the details of the next level subordinate activities (A1, A2, A3) which comprise the A0, Lead Battle, activity.

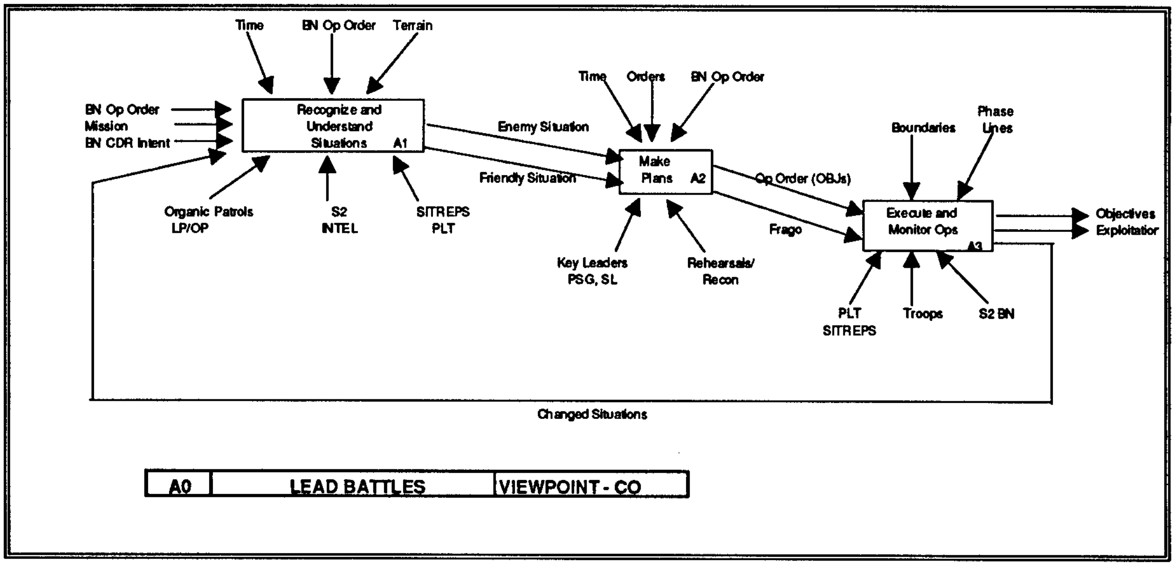


Figure 6.3 Decomposition Diagram of Lead Battle

We went on to construct decomposition diagrams for all of the node trees we created. Diagrams created with a professional quality software package, Design/IDEF™, can be found in Appendix D and E. Even a brief inspection of these diagrams demonstrates their value. The diagrams provide a way of understanding and explaining the details of any battlefield activity. And this is the first step that must be accomplished before the activity can be re-engineered.

Leading a company in battle is a very complex process. Activity modeling allows us to break the process down into more manageable steps. We could also use activity modeling to examine how technology might be integrated into a battlefield activity in order to improve it in some way. Inserting a new device or process into the model above might change the order, speed, and efficiency of leading a company in battle. Although this is a static model, it can form the basis for a simulation or dynamic model. There are software programs available on the market today, such as Design/IDEF, that can automatically generate a fully-executable simulation model by simply converting activity

models into a simulation model. Some of these simulation software packages, such as ServiceModel™, even include animation as part of the output so that users can see the simulated system in action.[5] A useful tutorial on how to build activity models is included as Appendix M.

6.3 Battlefield Architecture

Designing Force XXI so that it has the attributes outlined in 525-5, such as tailorable, rapidly expansible, strategically deployable, effectively employable, interoperable, and modular, depend on defining a smart architecture. Each Battle lab should be able to explain the battlefield and system architecture for their areas of concern and show how it fits within the overall Force XXI architecture. Therefore, some thoughts about architecture are appropriate.

First, architecture is a **scheme of arrangement or plan** of how all of the component parts of a system, such as a battlefield operating system, fit and work together. Architecture identifies the system, its subsystems, and their various components and describes how they are grouped together and their **relationship** to each other. Importantly this includes the identification and definition of the **interfaces** of the system, **both external interfaces**(to other battlefield operating systems), and internal interfaces (among the various subsystems and components of the system). Another important part of architecture includes a description of the **repeated elements** in the design. These repeated elements usually take the form of **standards** that various components of the

[5] Design/IDEF is a registered trademark of Meta Software Corporation, Cambridge MA and ServiceModel is a registered trademark of ProModel Corporation.

system must meet so that system-wide advantages, such as interchangeability or modularity, can be achieved.

For a complete description of the architecture of a system, there are three important perspectives. These three views are the functional, physical, and operational architecture. The **functional architecture** describes the various functions that a system and its components performs and diagrams how they relate to each other. A functional flow block diagram or a design IDEF activity model are excellent ways to diagram the functional architecture. The **physical architecture** of a system shows the various physical parts of a system usually in a hierarchical block diagram schematic. One of the important tasks of a systems designer is to **allocate the functions to the various physical components** of a system. But, perhaps the most important part of architecture is the **operational architecture** -- how does the system and all its parts actually work when it operates and where are its problems or limitations as it operates. To examine the operational architecture of a system, the system must be simulated in all its modes of operation and should be required to interact with the other systems that it will have to interoperate with in the actual operating environment.

When Battle Labs recommend changes to a battlefield operating system, they need to see how their recommended change will affect the functional, physical, and operational architecture. A useful example for thinking about architecture is to think about using a systems approach to design a house. The physical architecture could be described as the various rooms of the house and how they are part of the levels of the house assuming we are describing a multi-level house. Interfaces are the doorways between the rooms. The

repeated elements in the design could be the framing method used for the construction of the walls. Standards would be the many standard components used throughout the design such as the electrical outlets or fixtures and the standard size of studs used. The functional architecture of the house, from a user's viewpoint are such functions as sleeping, eating, washing, heating and cooling, storage, and others. Now we could make very different house designs by the way we allocate these functions to the various physical components or rooms and levels of the house.

But to really understand how well our designs might work, we would have to look at the operational architecture of the house and simulate how it might work when it was actually being used. So we might want to simulate our house for a family of four and take it through a daily weekday routine or normal operating mode. If everyone wakes up at about the same time and has to go to one location to wash and get ready for work then we may have identified a problem with our design, a bottleneck at the bathroom. So our operational architecture informs us that we need to duplicate the washing function in more than one physical location to alleviate the bottleneck.

But we also need to look at other modes of operation of the house. For example, consider an emergency mode of operation such as a house fire. If the house has only one exit and that exit is blocked by the fire, then we have identified another design problem. We need to change the physical and functional architecture by adding more exits for use especially during a fire emergency mode of operation. Although this is a simple example, it does illustrate the benefits of having a thorough understanding of the physical, functional, and operational architecture of Force XXI.

7.0 Real Operations - Task Force Ranger

First, we want to say that the all of Task Force Ranger performed very heroically in Somalia which was a very difficult operating environment, both tactically and strategically. However, it is vitally important to understand real operations so we can garner lessons learned and improve performance in future operations. This is even more true when considering how to re-design a force for the 21st century - the new force should capitalize on our current strengths and overcome any limitations that may exist. In this spirit, about 400 senior cadets and eight instructors enrolled in a systems engineering design course supervised by LTC Armstrong, studied unclassified reports of the Task Force Ranger operation in Somalia using a systems engineering framework. Each team developed their own interpretation of what went wrong, what went right, and made recommendations for the future. This section summarizes that work and its results.

The major observations and results of the work of the cadets focused on two related areas: command and control and information. Here are the results in brief. Samples of the work that led to these conclusions are at Appendix L.

7.1 Information

From the unclassified readings available to the cadets, Task Force Ranger appeared to suffer from a lack of information in several key areas. First, there seemed to be a lack of knowledge, or at least a sufficient appreciation, about how the enemy had organized its command and control structure and the capabilities this simple but effective organization gave the enemy. The enemy command and control structure, although

technologically simple, was very effective. They used a sector defense system linked together by walkie-talkies, drums, and messengers. It was successful at quickly mobilizing many armed Somalis into the fight and in coordinating the erection of a series of barriers covered by fire to entrap the extraction forces and block friendly reaction forces.

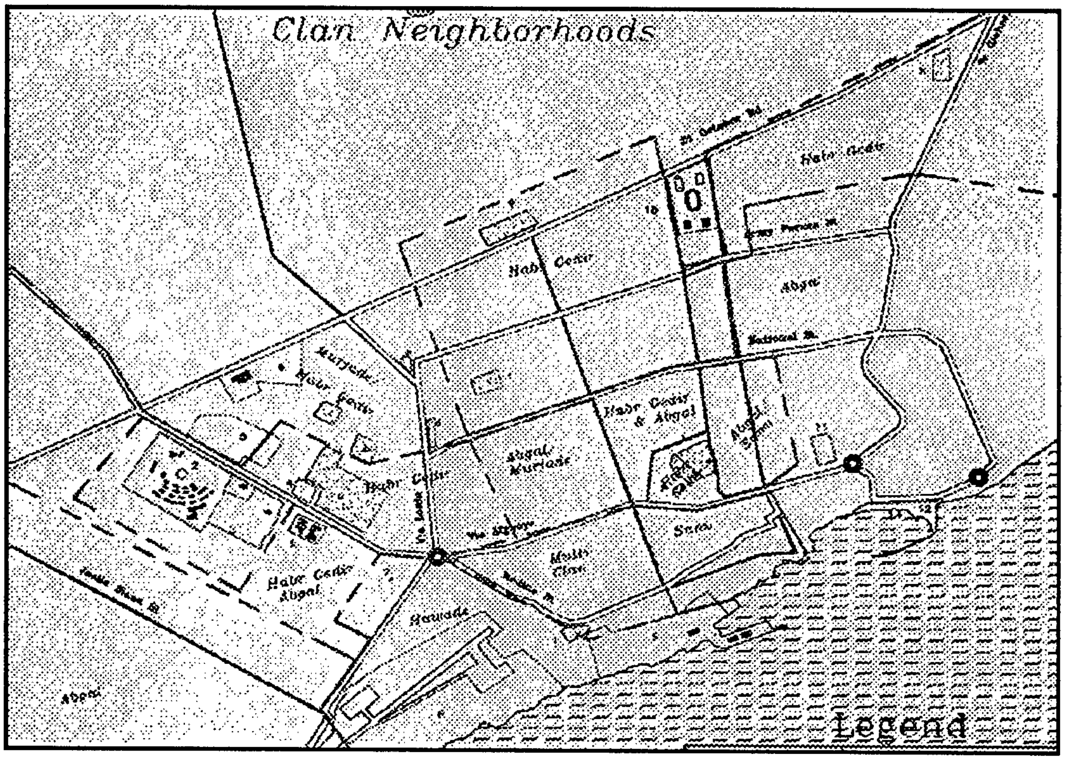


Figure 7.1 Overview of Clan Neighborhoods in Mogadishu, Somalia (Image - D/GEnE, USMA)

As can be seen in Figure 7.1, Mogadishu, like most underdeveloped urban areas lends itself to a sector defense arrangement. The sector defense is not new at all and has often been used especially in low intensity conflict. The area to be defended is divided up into sectors or blocks. A sector commander is appointed for each sector in the defended area. In brief, sector commanders establish communication links between each other and the forces they control. When a sector is threatened, the threatened sector sounds the alarm which is relayed to other sectors so they know which sector is in danger.

Neighboring sectors know in advance that their responsibility is to quickly mobilize reinforcements to the threatened sector as shown in Figure 7.2. Outlying sectors, more removed from the threat, are tasked to block likely routes that extraction or reaction forces might take.

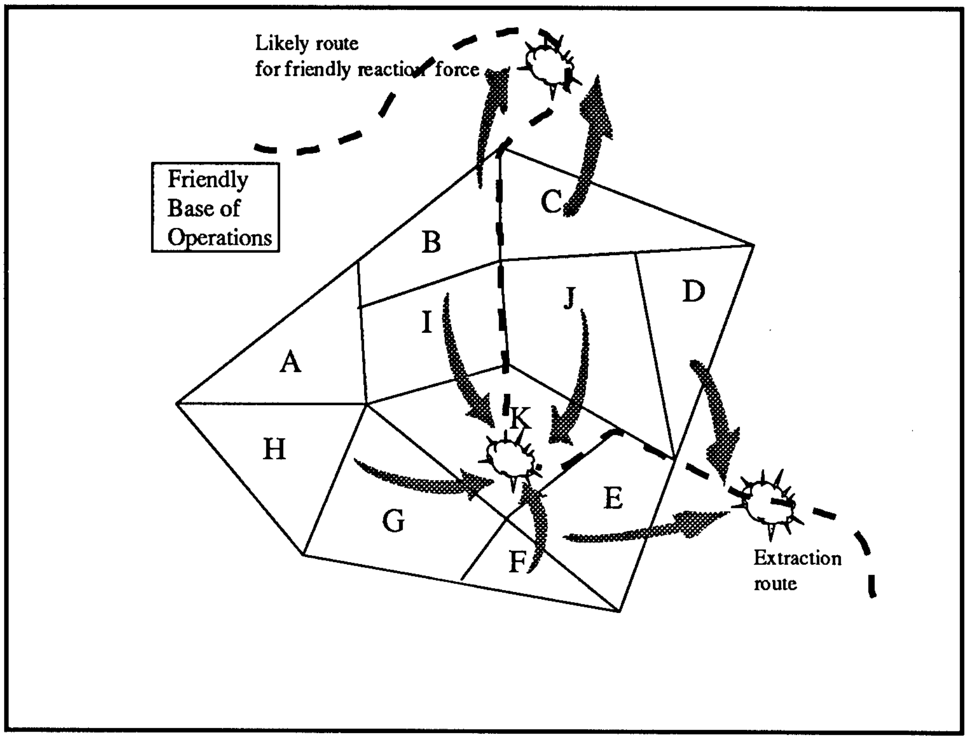


Figure 7.2 Typical Operation for a Sector Defense Plan

The reason the sector defense works so well is that the response of the defenders can be planned and rehearsed well in advance so that their reactions to a threat can be executed with great speed and flexibility. A vulnerability of the sector defense is that it can be distracted by false alarms or saturated by multiple simultaneous, or nearly simultaneous, threats. Most sector defenses only plan to respond to one threat. Once the sectors have been alerted to respond to a given threat in a certain sector it is very difficult for the defenders to reorganize the response to subsequent threatened sectors.

Since all of the decisions of the sector commanders, and the actions of the forces they control, are pre-planned in advance and well-rehearsed, it is very difficult for an intruding force, once detected, to get inside the observe-decide-act cycle of the sector defense. Once the battle is joined, the intruding force is at a big disadvantage because any actions they try to carry-out are in the enemy's neighborhood. This means that all of their actions are under constant enemy observation and perhaps fire as well. On unfamiliar and dangerous territory, the intruding force has to be cautious and take more time to plan and take actions. The sector defenders know the territory by heart and can quickly carry out many different actions that they have planned in advance.

Another indicator of the lack of information was the apparent under estimation of the Somalia capabilities for using **innovative tactics**. For example, not only was the Somali skill at organizing a sector defense under rated, but their ability to train and employ soldiers in groups to fire salvos of rocket propelled grenade launchers at helicopters was not anticipated.

The third indicator of the lack of information was the way that one of TF Ranger's important subsystems was apparently operating, their intelligence subsystem. Long ago, it was recognized by the Germans that their are several subsystems that are very important to the operation of an armed force and that these subsystems are so vital that they decided to put a staff officer in charge of each one of them. We are, of course, talking about the S1, S2, S3, and S4 who are in charge of the personnel, intelligence, operations, and supply subsystems of a military unit or system.

One of the breakdowns in TF Ranger appeared to be in the intelligence subsystem. From a systems viewpoint, we know that often failures occur in a system because of interface problems with other systems or due to faulty interactions among the components parts or subsystems of a system. In special operations, especially leader-snatch type operations, intelligence is crucial. The intelligence subsystem of TF Ranger was depending heavily on a dedicated interface to one specific, external human intelligence source. That interface broke down when the source shot himself in the head shortly before the operation. The planners of the operation apparently had not prepared alternative sources to compensate for the possible loss or compromise of this one source. Further, the intelligence sources external to TF Ranger were unable to provide needed information on the whereabouts of Aidid and his top aides on a consistent enough basis to make the chances for success of the operation higher. Despite these problems with information, the first phase of the TF Ranger operation was fairly successful because they were able to locate and capture some of Aidid top lieutenants. Unfortunately, command and control difficulties so complicated the rest of the operation, that success quickly evaporated.

7.2 Command and Control

The first problem with the command and control structure, aside from the complicated structure of UN multinational forces with US special operations forces, US Army forces and US Marines, was the rules of engagement and procedures for making changes to them. Apparently, the rules of engagement stressed minimizing casualties to

the enemy to the extent that even when the helicopter pilots saw Somalis passing out weapons and RPGs to their people, they did not fire on them to disperse them and prevent them from organizing themselves for the fight. By the time it was clear that the rules of engagement did not make any sense and needed to be changed, it was too late and helicopters were already fatally hit. Still the situation may have been stabilized if more firepower from the air could have been brought in but apparently none had been planned for and the commander on the scene apparently did not know how to change the rules of engagement or was too heavily engaged to worry about it.

The next command and control problem was that TF Ranger had no effective way to direct and control their forces in the twisted streets and confusing urban terrain of Mogadishu. When a helicopter was shot down and elements of the force were sent to its rescue, they could not navigate their way to the downed helicopter even though it was only several hundred yards away. By the time, elements could reach the helicopter, the Somalis had arrived with many of their troops.

Another command and control problem was the apparent poorly planned and organized procedure for controlling the extraction and reaction forces. Once the operation started to run into difficulty, there should have been a rapid extraction of all personnel by the quickest means available to designated rallying points. As soldiers fought bravely to save each other, control of this aspect of the operation deteriorated. As the vehicle ground route out of the area became next to impossible, there did not seem to be a good branch or sequel to the primary extraction plan. Reaction forces seemed to be slow getting notification and slow to arrive where they could do any good. Part of command

and control is making and disseminating plans that have been wargamed and well rehearsed. Perhaps the concern for secrecy prevented the proper preparation of the reaction forces. But with the situation extant in Somali, there should have been a daily standing alert or reaction forces with specified timelines that could have been chopped to the operation at a moments notice, on command. Proper information on the structure of the enemy's sector defense and capabilities should have highlighted the special needs of the reaction force such as heavy armor to break through barriers and helicopters for rapid fire support and extraction of personnel.

What can we do to make sure that future operations are more successful? In one sense, we could say that we should try to avoid these very difficult operating conditions. But realistically, we should know that the Army exists to go into difficult situations. So the answer has to be that we need to improve our knowledge of command and control, not just our knowledge of how we ought to operate and make decisions, but also make sure that **before we go into any operation that we have a thorough understanding of how the enemy command and control system works. This means we need to know how the enemy gathers and transmits information, makes decisions, and takes action.** Also, we need to significantly enhance the information capabilities of our forces. Stovepipe, single interface connections to external information sources about the enemy should not be acceptable practices for any military units in the information age especially special operations units.

Some of the analysis by the cadets may not be entirely correct because they were piecing together unclassified, open source reports about Task Force Ranger. Certainly

insiders who have access to classified information can probably point out errors in fact but given the same information that the cadets had to use for this analysis, even the insiders would probably admit that the cadet results appear very reasonable. Again, the cadets had great respect for the bravery of the soldiers in Task Force Ranger. Their motivation in studying this example was to learn so they could be the best leaders they can be. In fact, some of the cadets who participated in this analysis are now getting their chance to put these ideas into practice in Bosnia without the advantage of hindsight. Perhaps this exercise in hindsight will give them the foresight they need to lead bravely and wisely.

8.0 Recommendations and Conclusions

For the information in this report to be useful, it is essential that the Battle Labs take ownership. In other words, the Battle Labs must take hold of these ideas and implement them as regular processes. The use of objectives trees, a common terminology, crosswalks of AWE results with future doctrine, and activity modeling will all help in determining what the Army of the 21st century should be like. We believe that the following recommendations will help in structuring Force XXI. We display the six major objectives for this work in shaded boxes along with the major findings and recommendations summarized below each objective in clear text boxes.

To scope and bound Force XXI design efforts.

To scope the Force XXI design effort, we identified the **needs**, **objectives**, and **criteria** of Force XXI from a systems viewpoint. **Effective needs** are critical because *the definition of a successful design effort is meeting or exceeding the effective needs of the client or stakeholder group in a cost-effective, high-quality way.* So the effective needs must answer the question, "Why are we redesigning the Army to Force XXI?" Five statements drawn with some modification from TRADOC Pamphlet 525-5, in our opinion, answer this question. They are:

1. **To be trained and ready to win the first land battle with fewer, more economical but more capable forces.**

2. **To be rapidly tailorable, rapidly expansible, strategically deployable, and effectively employable as part of a joint and multinational team to achieve decisive results in future war and other operations in all environments.**

3. **To win simultaneous operations against foes of varying capabilities.**

4. **To find innovative ways to apply and combine current and new technologies, especially information technologies, for warfighting.**

5. **To win tactical battles quickly and decisively by maximizing information and combat power to dominate the battlespace.**

RECOMMENDATION 1: That the effective needs of the Force XXI design effort be clearly communicated to the Army to unite design efforts across organizations toward a common top-level goal. We propose the effective needs outlined above as a draft for senior decision makers to sharpen or revise.

To make Force XXI a reality, there are many lower level goals or objectives that should be pursued in a coordinated fashion to meet or exceed the effective needs of Force XXI. By parsing TRADOC Pamphlet 525-5, we identified more than seventy-five (75) objectives that Battle Labs and other Army organizations may want to pursue. We structured these objectives into a conflict matrix of six objective trees or hierarchies to reflect tactical, operational, and strategic concerns across war and operations other than war. These objectives trees represent everything that the Army must make significant progress on to make Force XXI operations a reality.

RECOMMENDATION 2: That Battle Labs and other Army organizations identify objectives and structure their objectives into objective trees, similar to the ones contained in this report, so they can have a coherent picture of everything they intend to accomplish to make significant progress toward Force XXI.

One of the findings from the Battle Lab visits was that they had difficulty articulating their objectives and understanding the objectives that they shared with other organizations. It is hard to make progress toward a goal when you don't know where you are going. Note that this does not conflict with the idea of a "journey not a destination." The kind of objectives that are outlined in this report are statements of intent that allow for many different alternatives and do not identify specific programs, systems, or technologies.

Again, the objectives in this report are draft objectives, mostly extracted from TRADOC Pamphlet 525-5 and should be considered as illustrative examples. For the objectives to be worthwhile, each Battle Lab should create their own set of Force XXI objectives and then their should be a master integration effort of the objectives across the Battle Labs. The final structure of objectives should be integrated into subsequent revisions of Army doctrine so that organizations can pull together to accomplish them.

RECOMMENDATION 3: That each Battle Lab develop meaningful, measurable criteria for their objectives. In this way, Battle Labs can determine how much progress they are making towards achieving their objectives.

The objectives trees will help Battle labs develop meaningful measures that they can use in experiments. Although higher level objectives may be difficult to measure, it should be possible to develop measurable criteria for each lower level objective. A weighted combination of lower level criteria can be used to measure a higher level objective.

RECOMMENDATION 4: That Battle Labs should construct anti-objective trees which show objectives that counter the enemy's objectives. A sample anti-tree is in the report.

To bound a design means to identify the constraints, parameters, and variables of the problem. Constraints are the limits that are placed on the design solution and help to focus the design efforts toward feasible options. Parameters are elements of the design which can be changed to help define competing alternatives but they do not change once a particular alternative is in operation. For example, the number of tanks in a tank company or the number of soldiers in any infantry squad are design parameters of a force that can be changed to define different force options.

Variables are important quantities that we want to monitor as the design alternative actually operates or is simulated. For example, we want to know the cost of various force design options in terms of friendly casualties suffered in likely conflict scenarios. To make meaningful design progress, we need to know what can and what cannot be changed and how important variables are affected by different design choices. Here are some sample design constraints, parameters, and variables for Force XXI, some of which we extracted from TRADOC Pamphlet 525-5:

Constraints (Things we must adhere to as we design force options.)

- Keep a division base
- Maintain soldier focus
- Full dimensional force
- Change leader-to-led ratio

- Modular combat support and combat service support
- Smaller staffs
- Smaller units
- Mobile, multi-functional command posts
- Incorporate cybernetic or feedback mechanisms for adaptation and innovation
- And more

Parameters (Things we can change to create different options.)
- Number of command echelons in a division
- Number of control elements at each command echelon (e.g., tactical command posts)
- Number of staff elements at each command echelon
- Type of staff elements at each echelon
- Number of staff personnel in each element
- Number of units in each echelon of command
- Type of units in each echelon
- Number of systems (e.g., tank, Infantry Fighting Vehicle) in each unit
- Type of systems in each unit
- Number of soldiers in each crew or squad
- Type of soldiers in each crew or squad
- Type of units in the division base
- Size of units in the division base
- Number of functions performed at each echelon, unit, or element
- Type of function performed at each echelon, unit, or element.
- And more

Variables (Things we must monitor when we exercise or simulate force options)
- Amount of battlespace that can be dominated or controlled by the force
- Force recognition time (time that it takes for the force to recognize significant battlefield situations)
- Force response time (time that it takes for the force to respond to significant battlefield situations once recognition has occurred)
- Force tempo (the number of significant battlefield situations that the force can recognize and respond to in some specified unit of time)
- Number of enemy systems killed
- Number of friendly casualties
- Consumption rates (ammunition, fuel, food, expendable supplies)
- And many more

In addition to internal thinking about how the Army can change itself, we need some "out of the box" thinking about how the other services, that are part of the joint team, could change to make the overall team more efficient and effective. For example, are there

functions or activities that take up a significant part of the Army's budget that should be offloaded to another service or are their better ways that other services could accomplish their functions and activities that would generate a savings that could be put to good use by the Army. Perhaps there are functions and activities that the Army performs for other agencies that should be done on a reimbursable basis. The systems point of view calls for examining not just redesigning the Army put also understanding how the Army should fit and work with all the other systems in its operating environment.

RECOMMENDATION 5: That Battle Labs, in their areas of expertise, help senior decision makers identify the design constraints that must be met and the design parameters that can be manipulated to create viable design options. Also, that Battle Labs determine how the variables of interest change for different design options across different operating environments and scenarios. This requires that Battle Labs have access to a robust modeling and simulation capability.

To help establish a coherent framework and consistent terminology for Force XXI.

RECOMMENDATION 6: That the terms and definitions for Force XXI Operations doctrine be simplified as much as possible since doctrine needs to be soldier friendly. Currently there are many compound terms with lengthy definitions. Sample, simplified definitions of some key terms and concepts are in the report.

RECOMMENDATION 7: That a cybernetic or feedback control type paradigm of military conflict be incorporated into Army doctrine by using simple diagrams of sense-decide-act to help soldiers understand the relationship between information operations and combat operations. A sample diagram is in the report.

To help understand past Army Warfighting Experiments (AWEs), Advanced Technology Demonstrations (ATDs), and real operations in terms of their impact on designing Force XXI.

RECOMMENDATION 8: That the results of Army Warfighting Experiments (AWEs) be crosswalked with the main ideas in TRADOC Pamphlet 525-5 to identify trends that confirm or refute doctrinal ideas and to identify knowledge gaps where we need additional experimentation. A sample method to accomplish this with a crosswalk and results matrix is in the report.

RECOMMENDATION 9: That Battle Labs analyze recent real operations to understand shortcomings associated with their areas of oversight. A sample analysis of a recent operation is in the report. To accomplish this, the Battle Labs will need access to information about these operations, including perhaps real-time observers and qualified military operations analysts.

To help improve Battle Lab processes.

RECOMMENDATION 10: That Battle Labs develop a more detailed understanding of the battlefield activities they are trying to improve by constructing activity models (IDEF0) of their battlefield activities. A sample battlefield activity model for leading infantry battle complete with node trees and decomposition diagrams is in the report.

This does not imply that Battle Labs do not understand their battlefield activities. Rather, it means that the Battle Labs have difficulty explaining these activities to others and in communicating their reasons and justifying the value-added of particular technologies or other changes they want to make to the way they accomplish their battlefield activities.

RECOMMENDATION 11: That Battle Labs adopt and use a systemic, life-cycle process for the identification, assessment, and preliminary implementation of technology. This life-cycle has seven (7) important and related steps: **Scouting, Documentation, Assessment, Selection, Tracking, Disengaging, and Supporting**. More details on how this process works is in the report. To accomplish this, the Battle Labs will need **"Technology Scouts"** out immersed in the commercial sector who know the Army and can understand technology and its potential applications to warfighting.

RECOMMENDATION 12: That the Battle Labs develop a better understanding of battlefield and system architecture. This includes not just the physical and functional architecture but also the **operational architecture** for their area of concern-- how does it work when it is actually put into operation and where are the problems that arise during different modes of operation.

The recommendations from this work, if put into action, should help support the Battle Labs and other Army organizations and offices to make and evaluate progress on Force XXI

References

Appleton, D. Co. Inc. (1993). *Corporate information management process improvement methodology for DoD functional managers.* Fairfax: D. Appleton Co. Inc. 2nd ed.

Armstrong, J. E. (1993, August). *Designing, testing and using command, control, comunications, computer and intelligence (C4I) systems: what causes the disconnects and what can be done about them*? Newport: Naval War College.

Atkinson, R. (1994, January 30). *The raid that went wrong; how an elite U.S. force failed in Somalia.* The Washington Post, Sunday, final edition.

Beam, W. R. (1990). *Systems engineering: architecture and design.* New York: McGraw-Hill.

deCzege, H. W. (1984, February 10). *Understanding and developing combat power.* unpublished paper.

Dewar, J. (1995, November 27) *Force XXI assumptions based planning analysis.* RAND (Draft).

Grossman, J. (1994, September) *Conducting warfighting experiments at the National Training Center.* RAND (Draft).

Starry, M. (1994, September 7). *Analytic foundations for the long view.* unpublished memorandum.

Strassmann, P. A. (1994, October) *Twenty force XXI "information operations" issues.* unpublished memorandum.

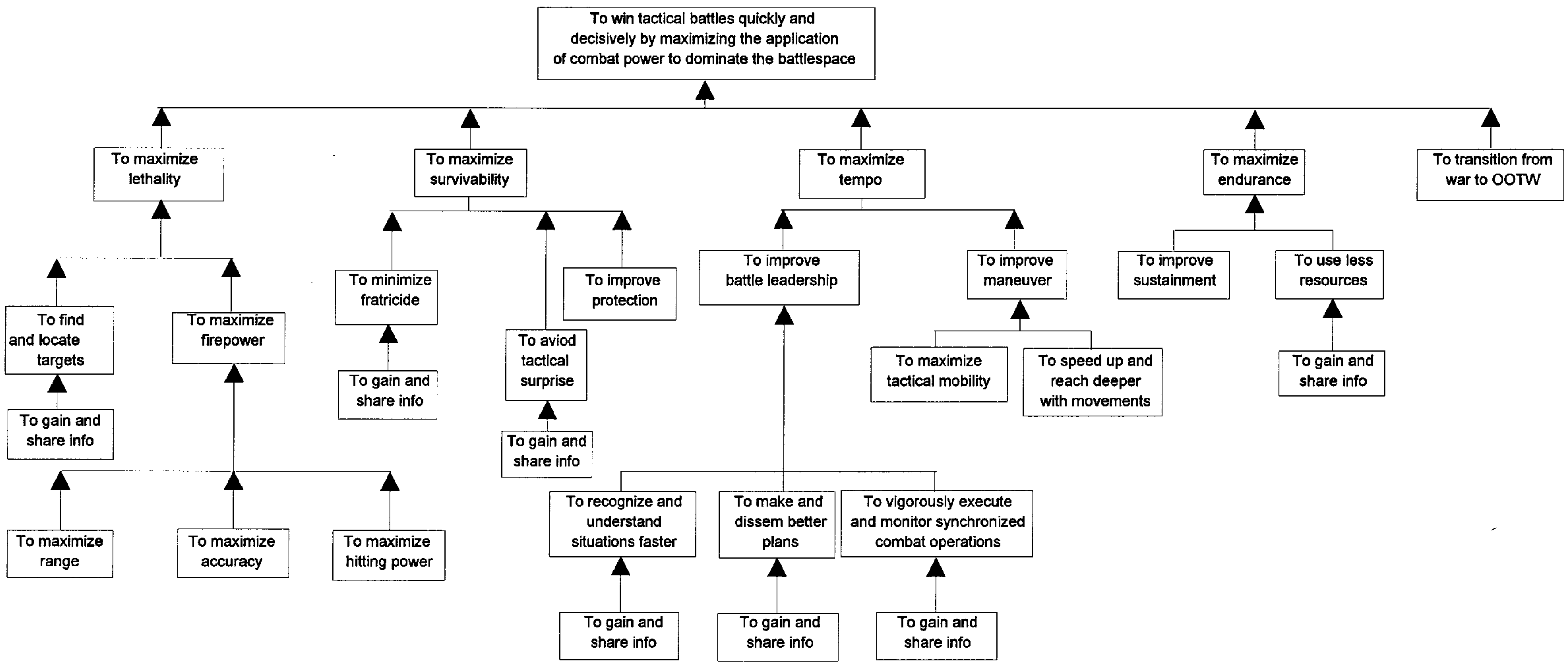
Sage, A. P. (1992). *Systems engineering.* New York: John Wiley.

United States Army. (1994, August). *Force XXI Operations.* TRADOC Pamphlet 525-5. Washington, DC: U.S. Government Printing Office.

Appendix A

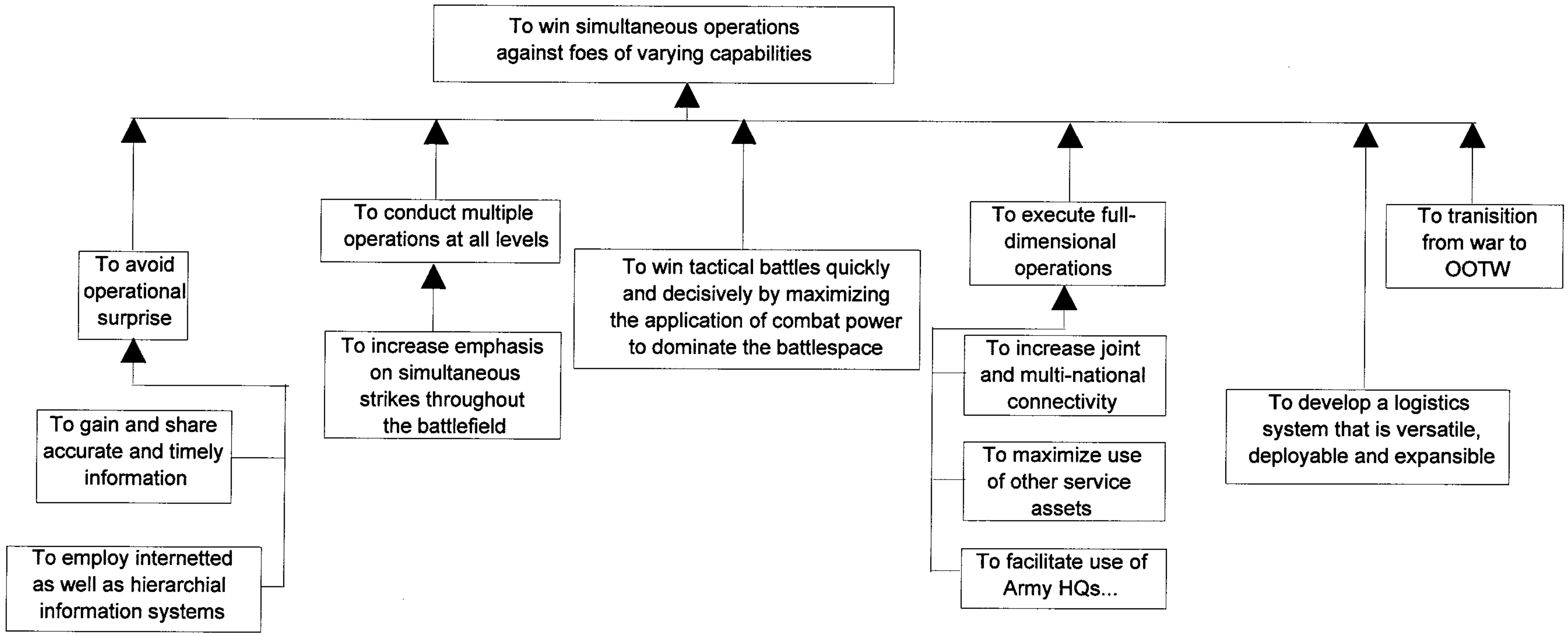
Objectives Trees - War

TACTICAL-WAR



CDT H. Jay Brock
LTC James E. Armstrong Jr.

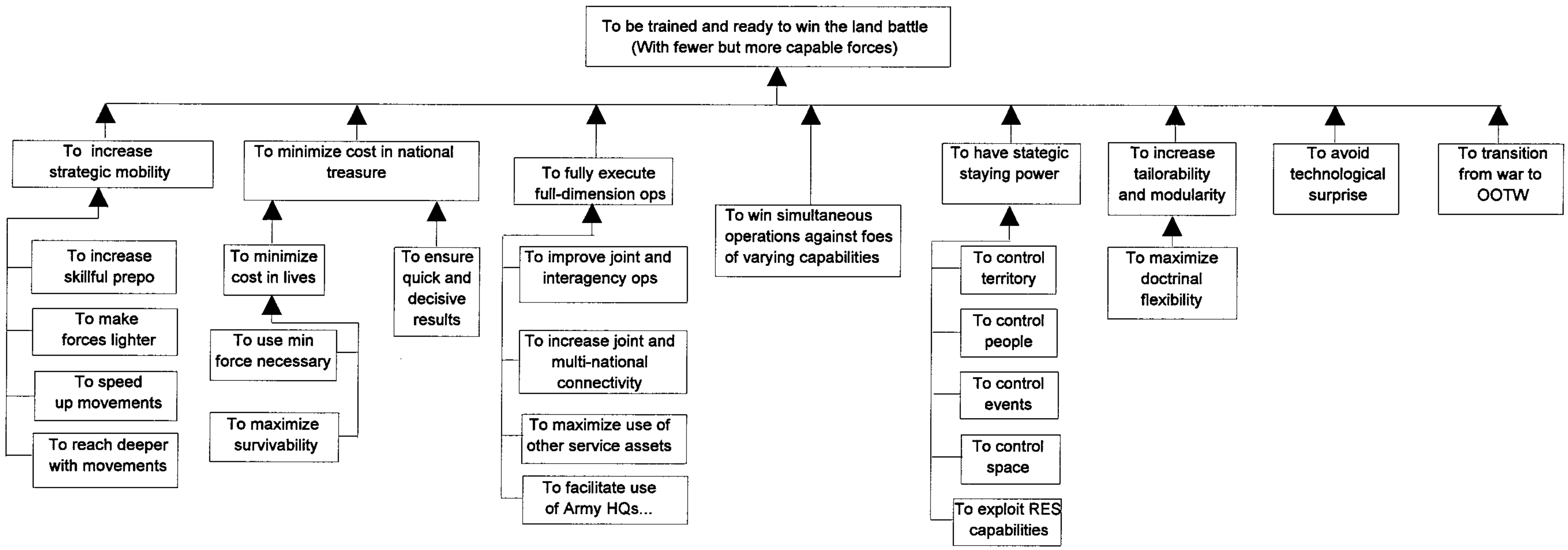
OPERATIONAL-WAR



CDT H. Jay Brock
LTC James E. Armstrong Jr.

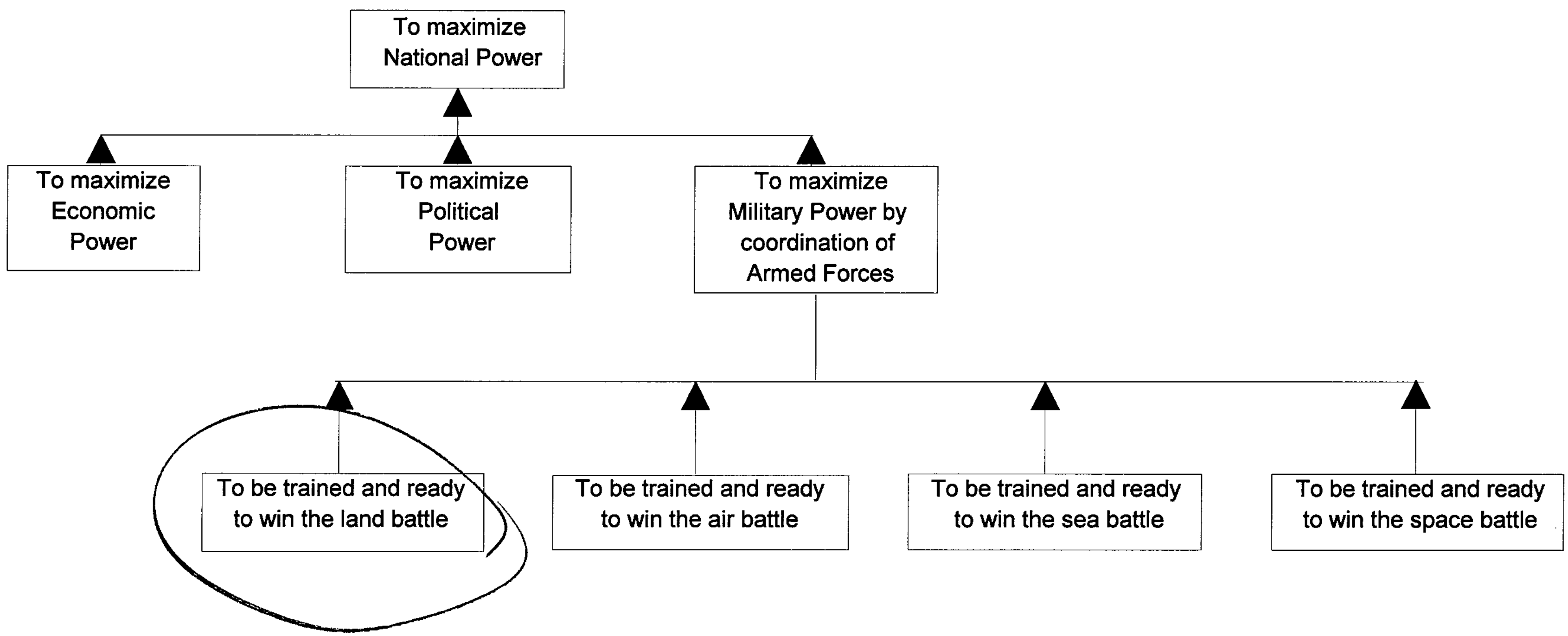
A4

STRATEGIC-WAR



CDT H. Jay Brock
LTC James E. Armstrong Jr.

National Power



= "will help to achieve"

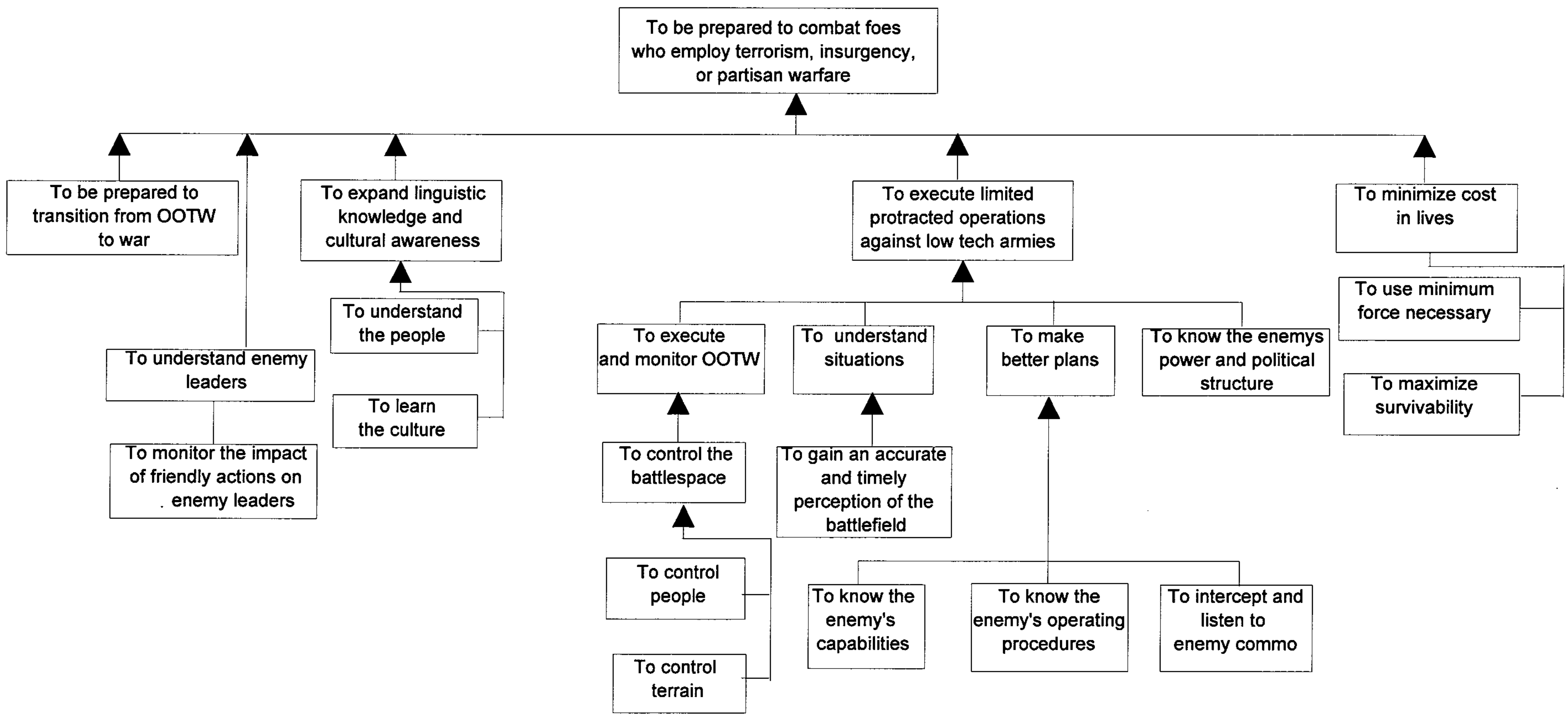
A5

CDT H. Jay Brock
LTC James E. Armstrong Jr.

Appendix B

Objectives Trees
Operations Other Than War

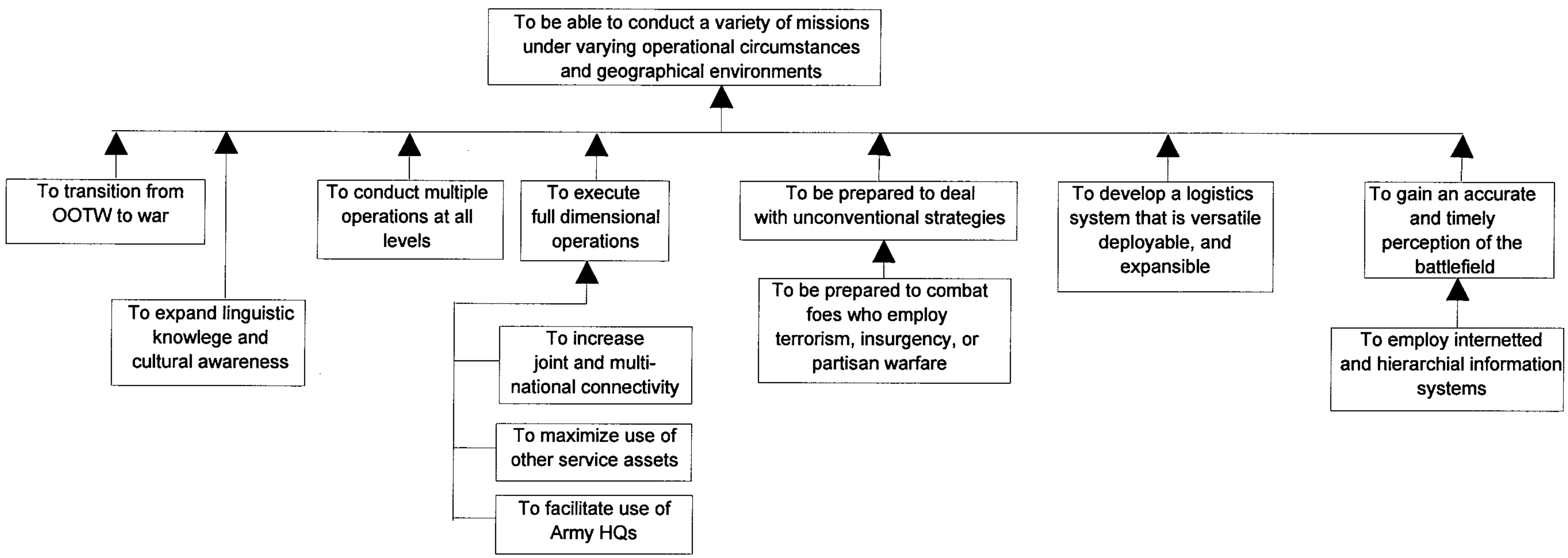
TACTICAL-OOTW



B2

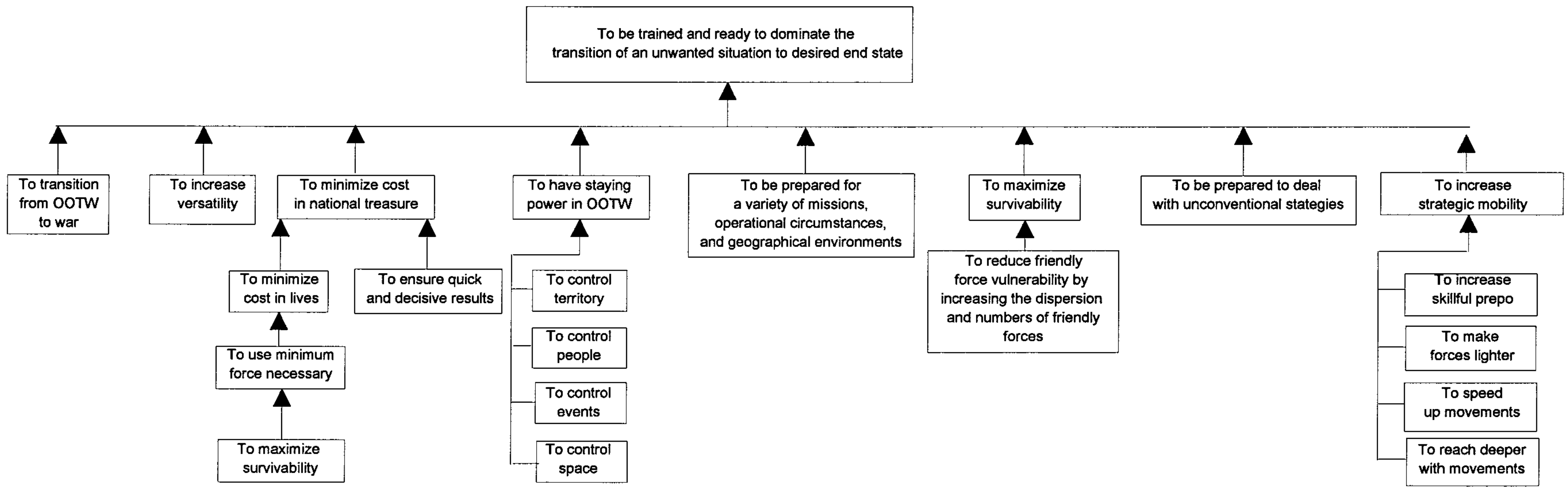
CDT H. Jay Brock
LTC James E. Armstrong Jr.

OPERATIONAL-OOTW



CDT H. Jay Brock
LTC James E. Armstrong Jr.

STRATEGIC-OOTW



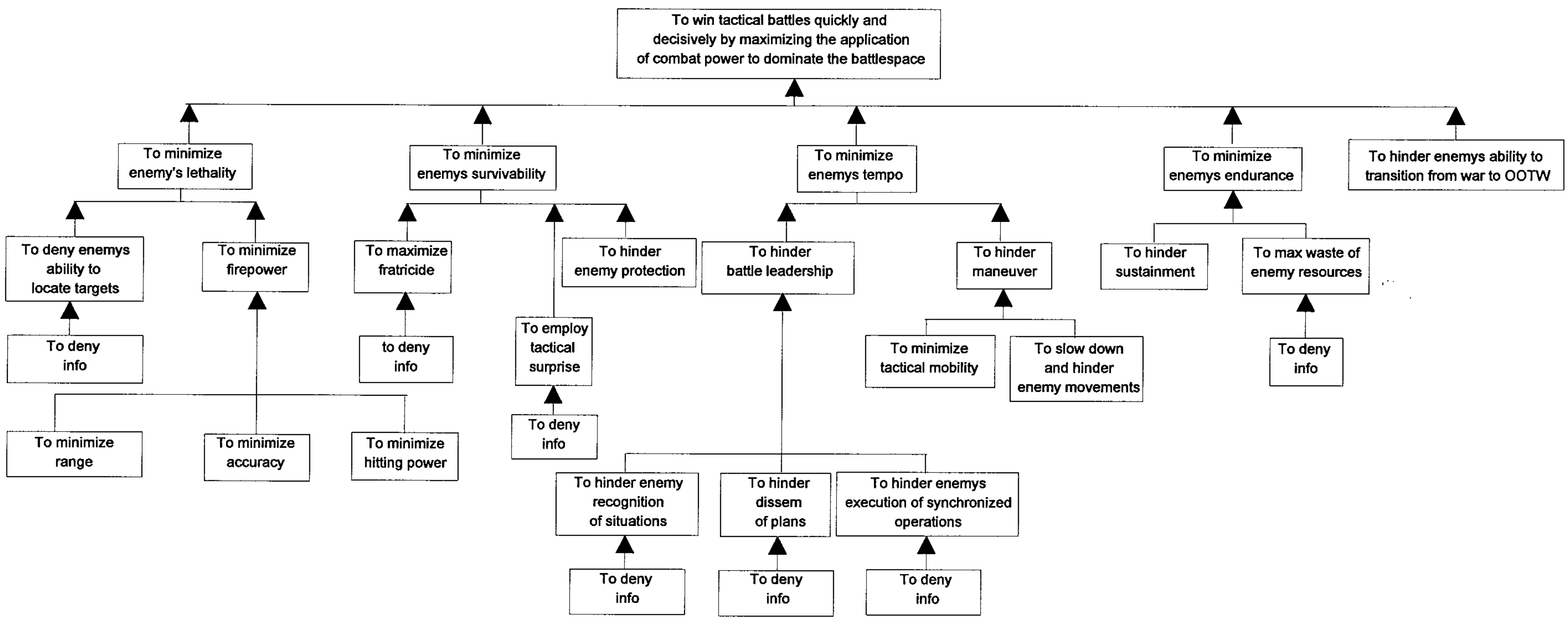
84

CDT H. Jay Brock
LTC James E. Armstrong Jr.

Appendix C

Anti-Objectives Tree
War at the Tactical Level

ANTI-TACTICAL WAR



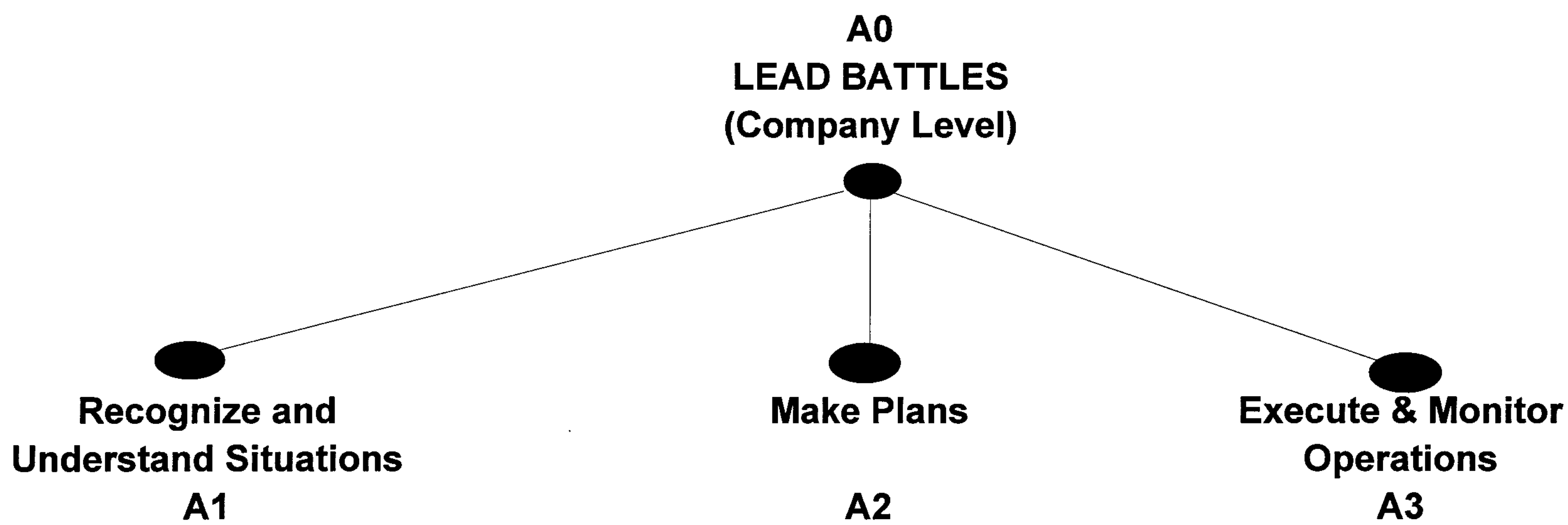
c2

CDT H. Jay Brock
LTC James E. Armstrong Jr.

Appendix D

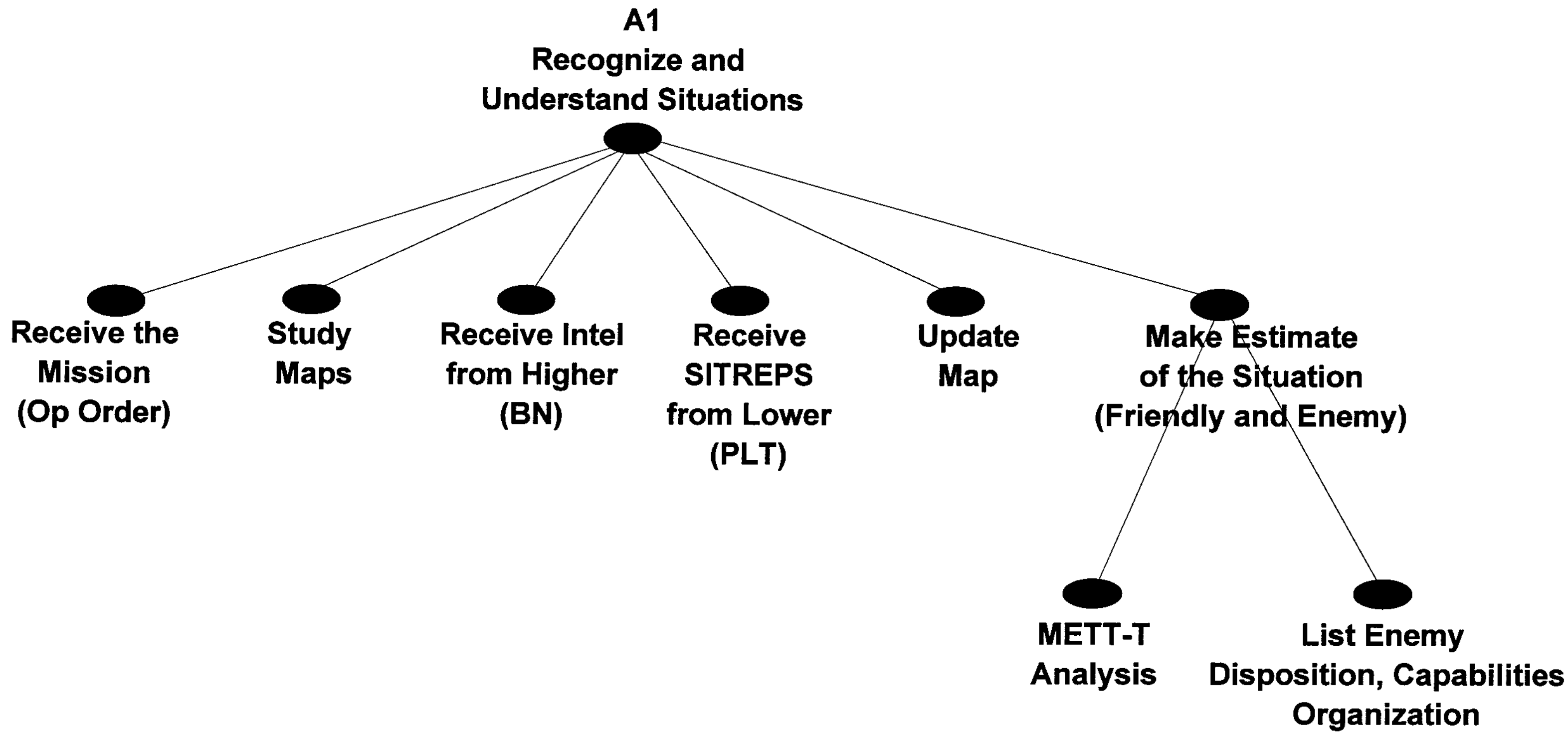
Node Tree Diagrams for the Activity of Lead Battle

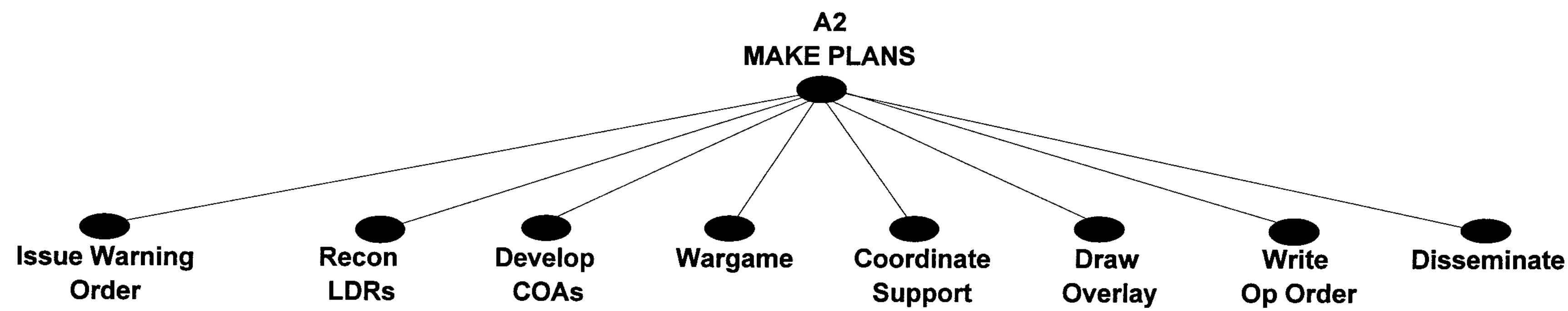
Node Tree-Lead Battles



D2

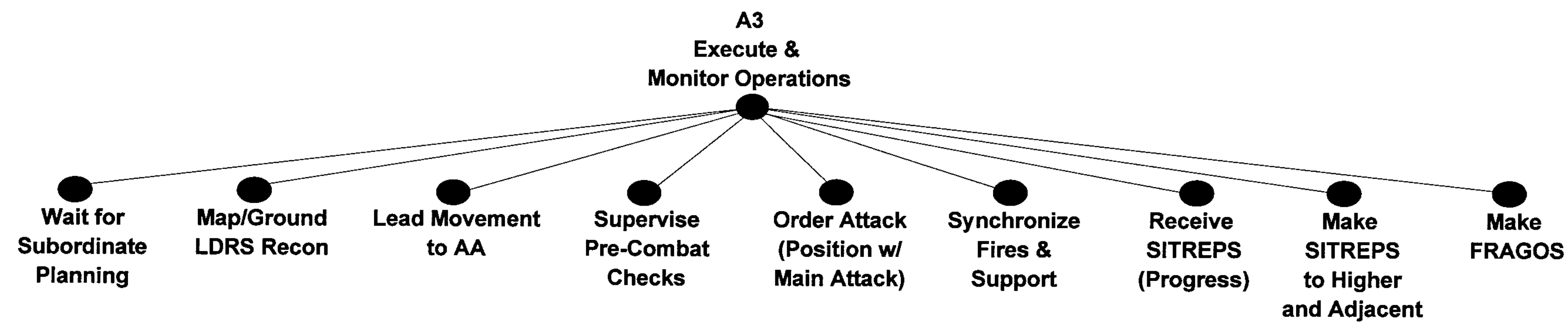
D3


A1
Recognize and
Understand Situations
Receive the
Mission
(Op Order)
Study
Maps
Receive Intel
from Higher
(BN)
Receive
SITREPS
from Lower
(PLT)
Update
Map
Make Estimate
of the Situation
(Friendly and Enemy)
METT-T
Analysis
List Enemy
Disposition, Capabilities
Organization


A2
MAKE PLANS
Issue Warning Order
Recon LDRs
Develop COAs
Wargame
Coordinate Support
Draw Overlay
Write Op Order
Disseminate

D4

D5

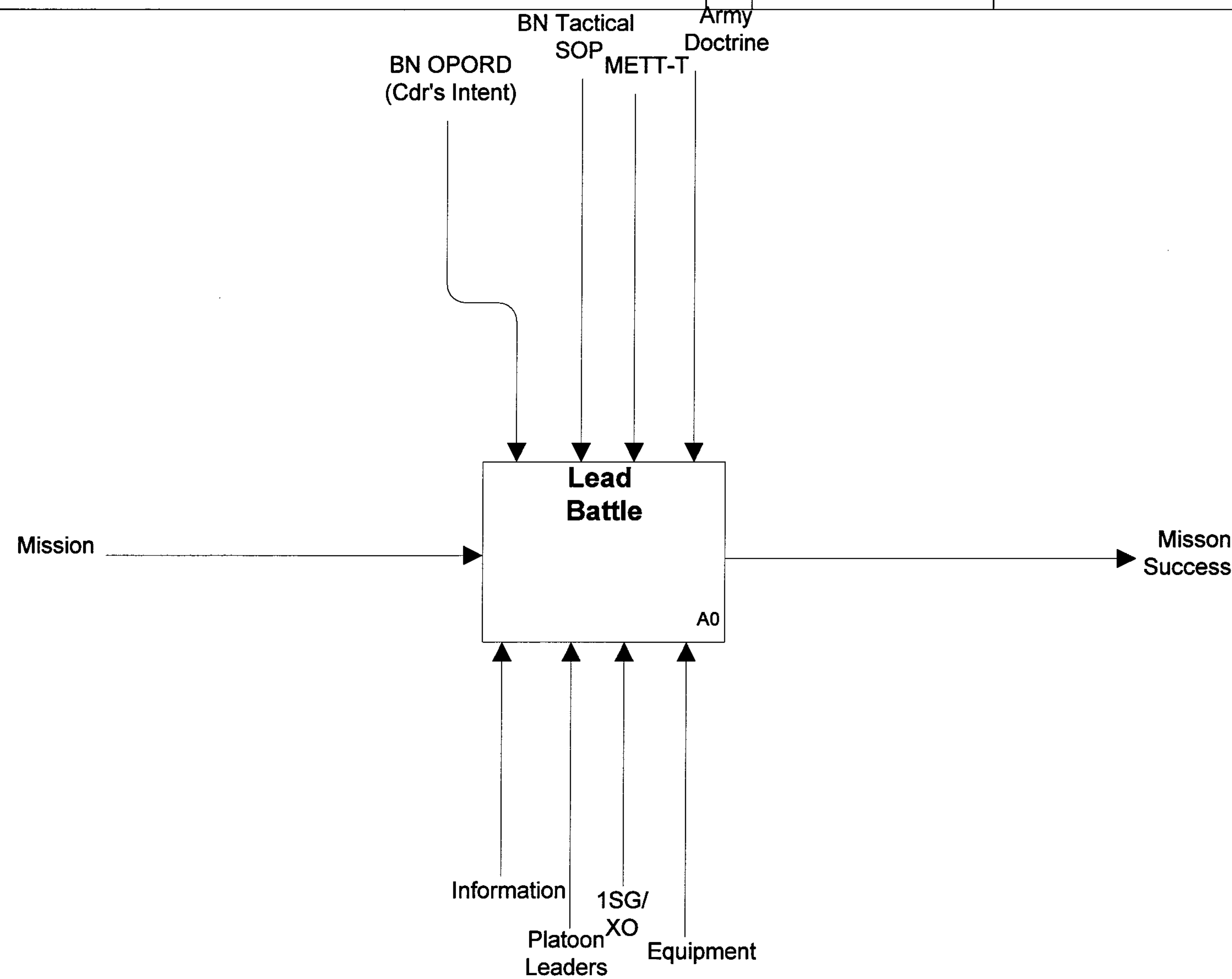

A3
Execute &
Monitor Operations
Wait for Subordinate Planning
Map/Ground LDRS Recon
Lead Movement to AA
Supervise Pre-Combat Checks
Order Attack (Position w/ Main Attack)
Synchronize Fires & Support
Receive SITREPS (Progress)
Make SITREPS to Higher and Adjacent
Make FRAGOS

Appendix E

Decomposition Diagrams for Lead Battle

USED AT:	AUTHOR: Armstrong/Brock/Brown PROJECT: Commander's Tasks NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 22 Jan 96 REV: 2	X	WORKING	READER	DATE	CONTEXT: Top
				DRAFT			
				RECOMMENDED			
				PUBLICATION			

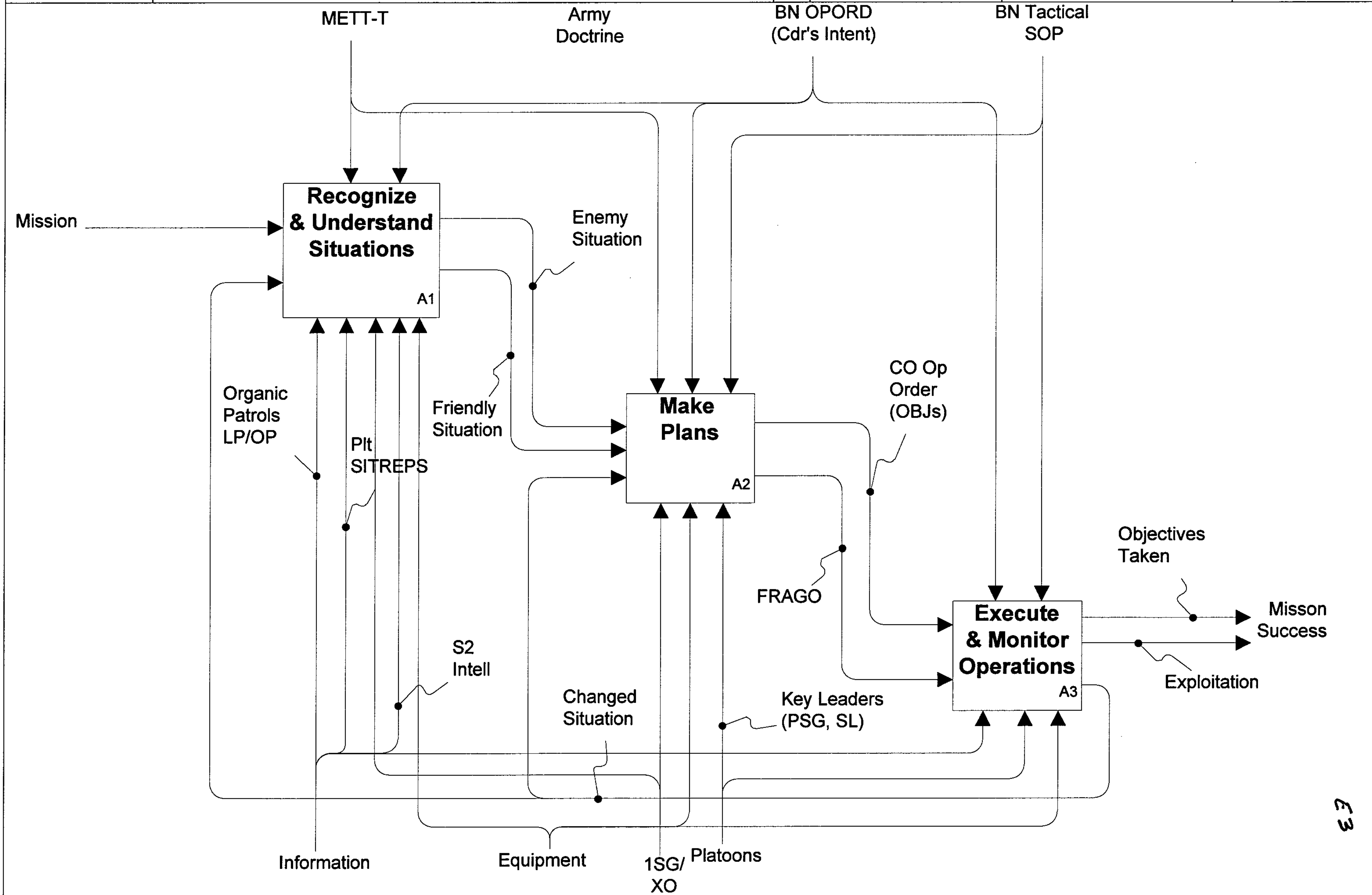
E2



PURPOSE: To define the tasks to be performed while leading in battle.
VIEWPOINT: Company Commander

NODE: A-0	TITLE: Leader's Battle Tasks	NUMBER: P. 1

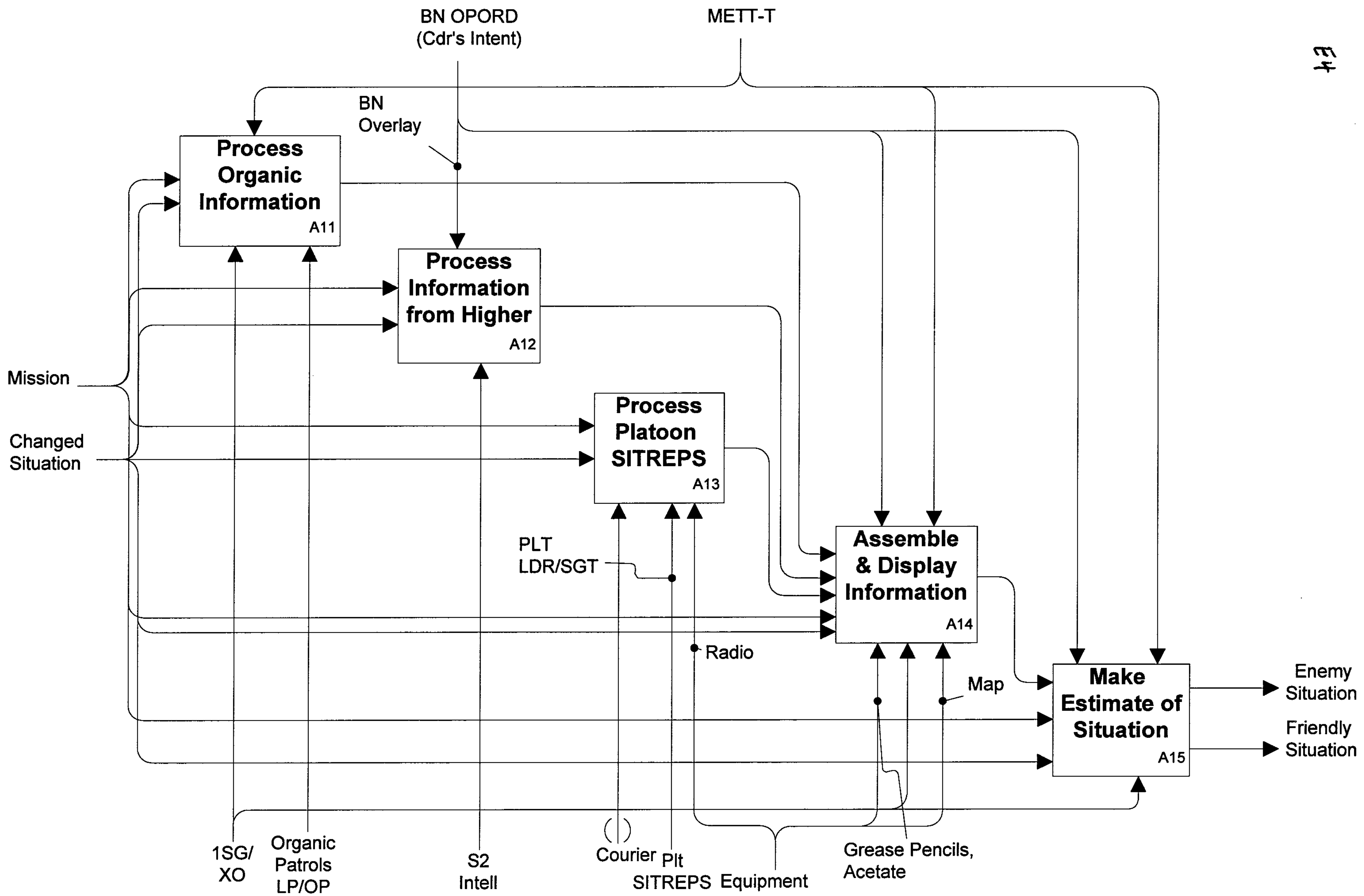
USED AT:	AUTHOR: Armstrong/Brock/Brown PROJECT: Commander's Tasks NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 22 Jan 96 REV: 2	X	WORKING	READER	DATE	CONTEXT:
				DRAFT			
				RECOMMENDED			
				PUBLICATION			



E3

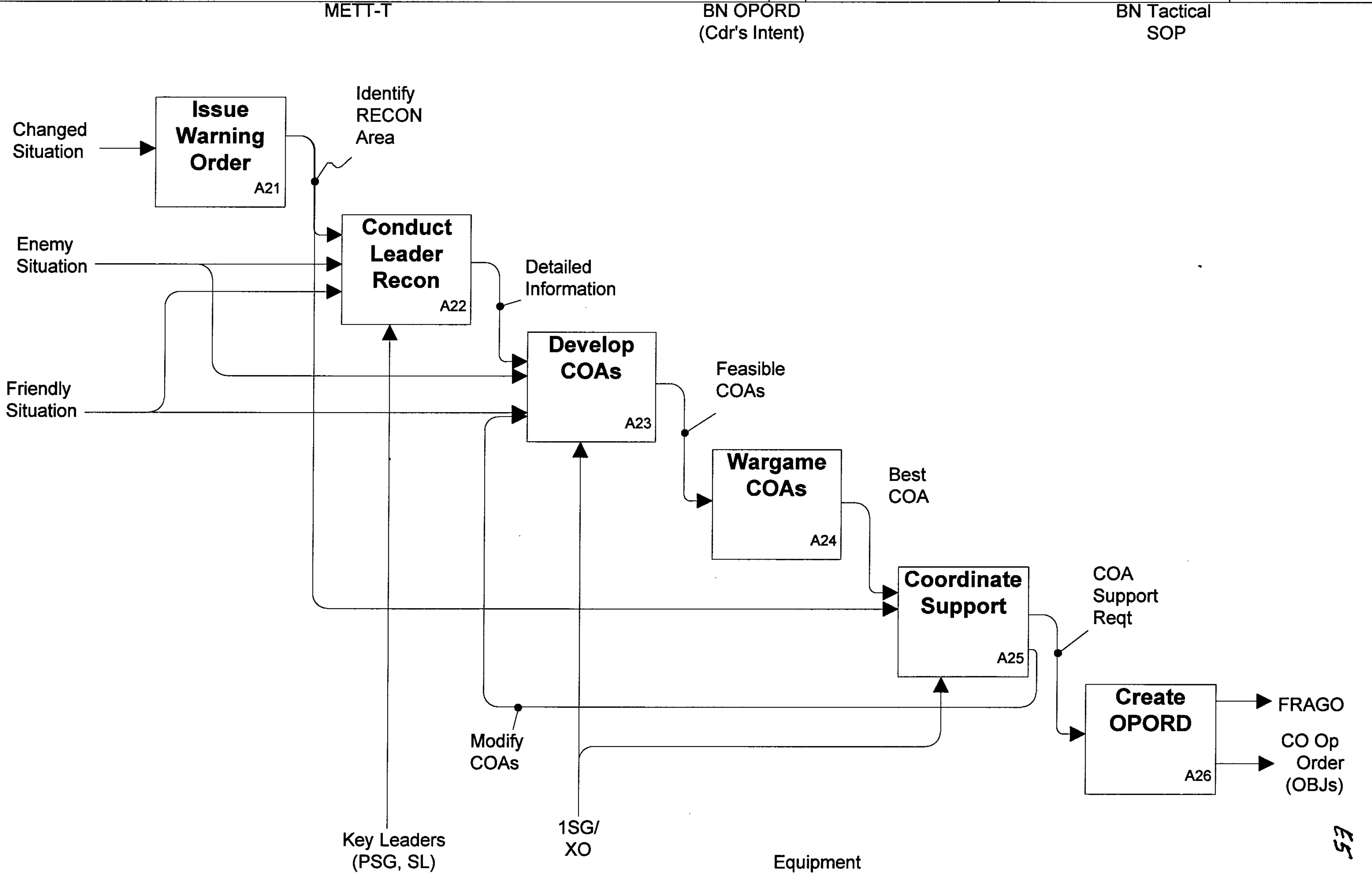
NODE: A0	TITLE: Lead Battle	NUMBER: P. 2

USED AT:	AUTHOR: Armstrong/Brock/Brown PROJECT: Commander's Tasks NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 22 Jan 96 REV: 2	X	WORKING	READER	DATE	CONTEXT:
				DRAFT			
				RECOMMENDED			
				PUBLICATION			



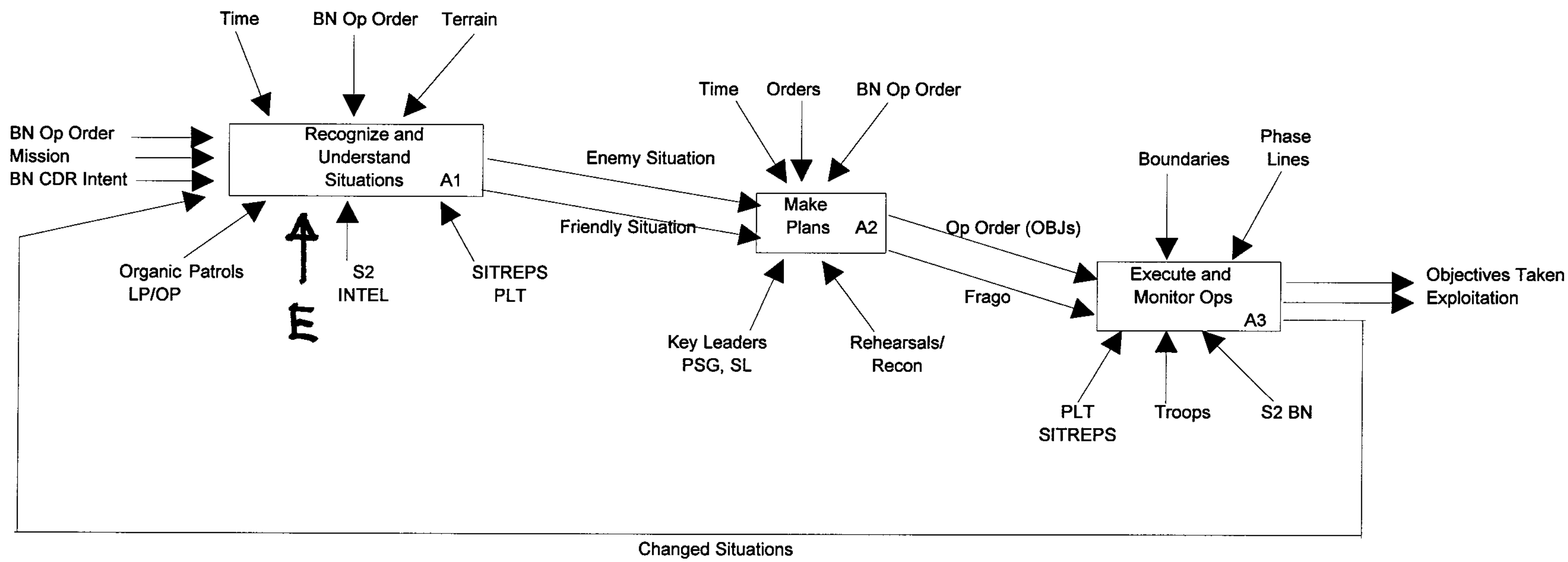
NODE: A1	TITLE: Recognize & Understand Situations	NUMBER: P. 3

USED AT:	AUTHOR: Armstrong/Brock/Brown PROJECT: Commander's Tasks NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 22 Jan 96 REV: 2	X	WORKING	READER	DATE	CONTEXT:
				DRAFT			
				RECOMMENDED			
				PUBLICATION			



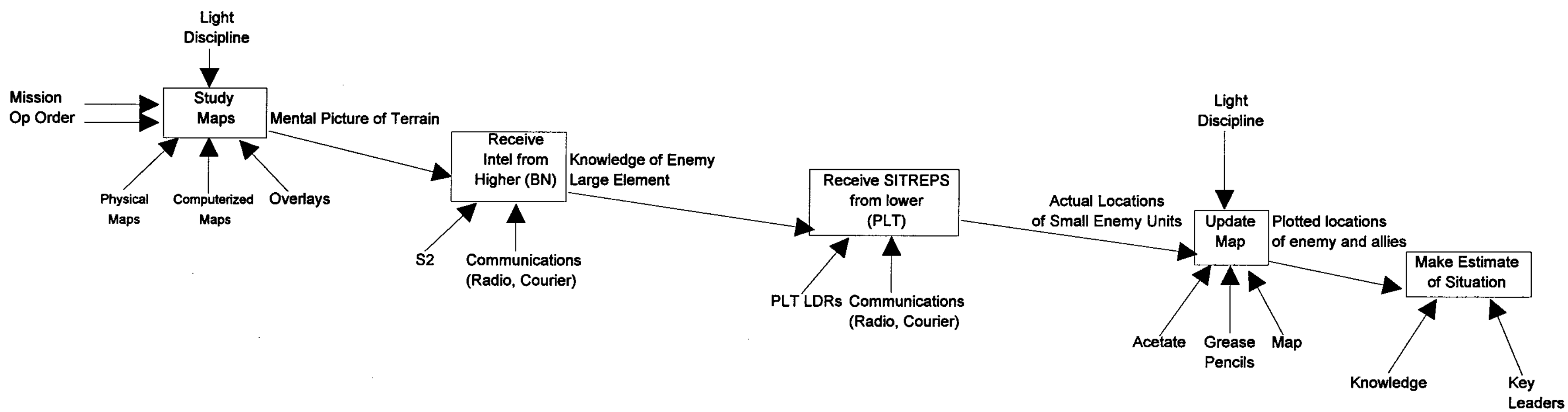
NODE: A2	TITLE: Make Plans	NUMBER: P. 4

E6



A0	LEAD BATTLES	VIEWPOINT - CO

Recognize and Understand

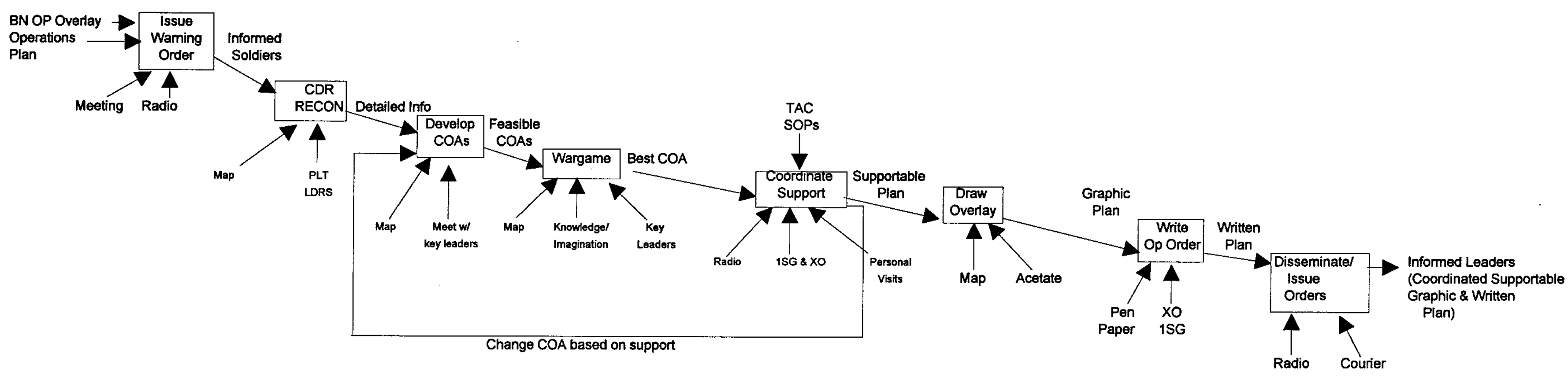


A1	RECOGNIZE AND UNDERSTAND SITUATIONS	VIEWPOINT-CO

E7

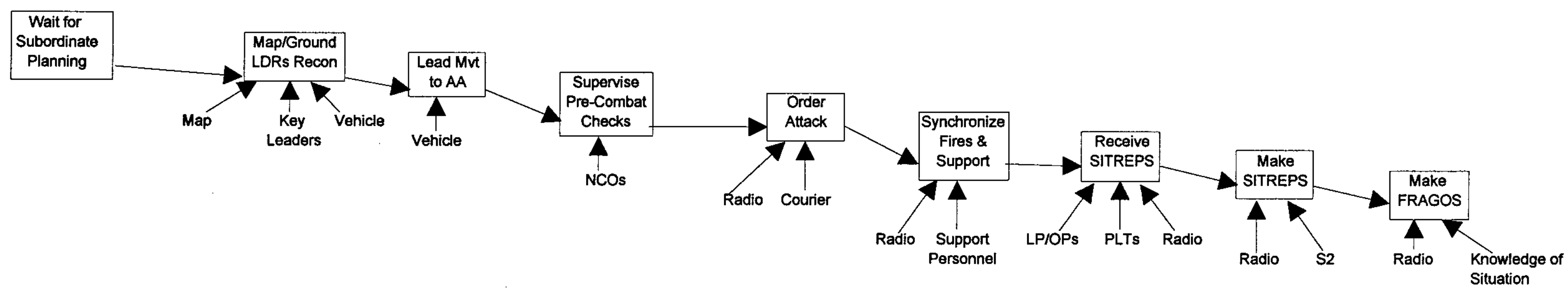
Make Plans

E8



A2	MAKE PLANS	VIEWPOINT-CO

Execute and Monitor

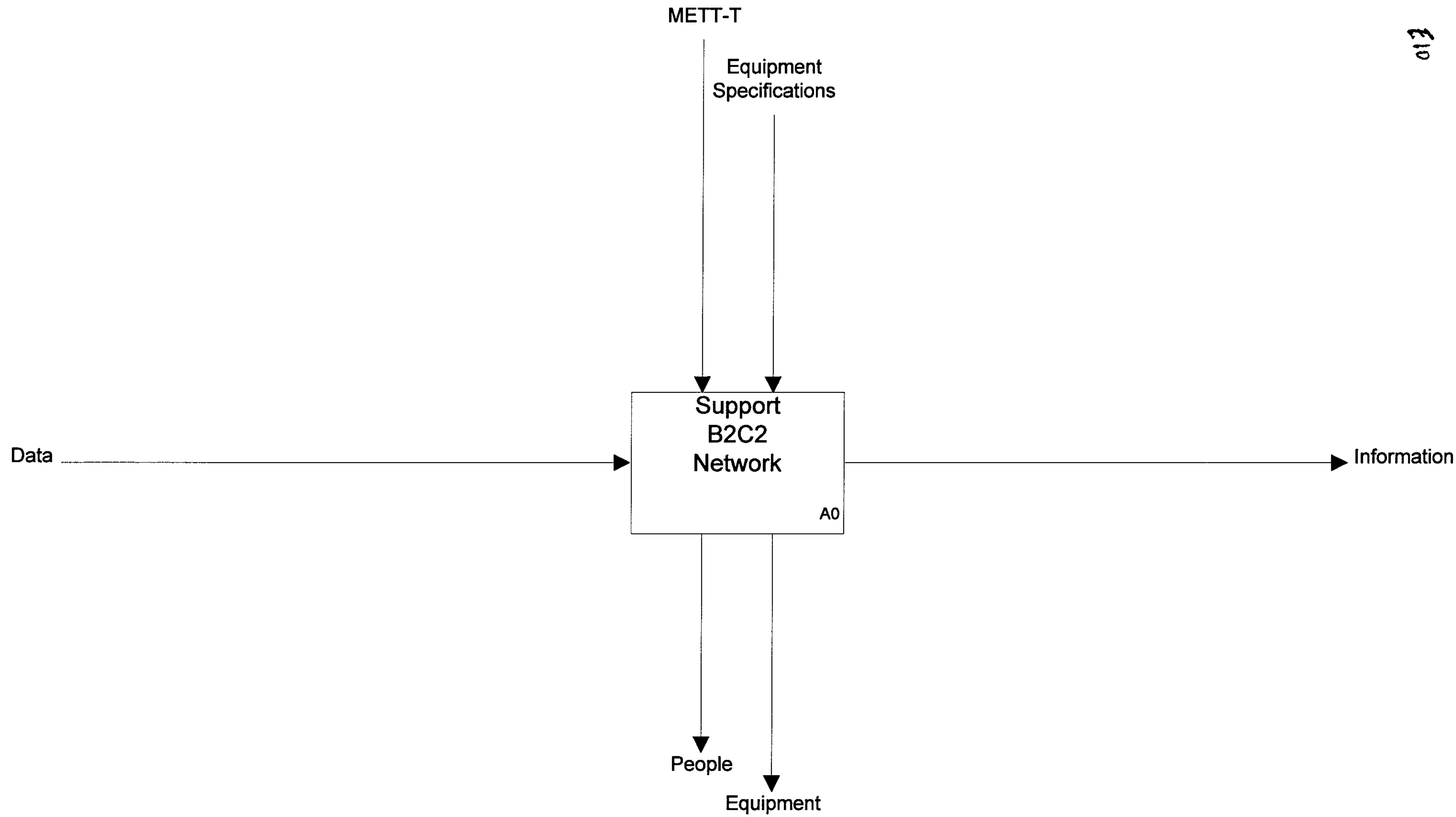


A3	EXECUTE AND MONTIOR OPERATIONS	VIEWPOINT-CO

E9

USED AT:	AUTHOR: Brown, C. M. PROJECT: Support to B2C2 NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 20[illegible] 96 REV: 1	X	WORKING	READER	DATE	CONTEXT:
				DRAFT			Top
				RECOMMENDED			
				PUBLICATION			

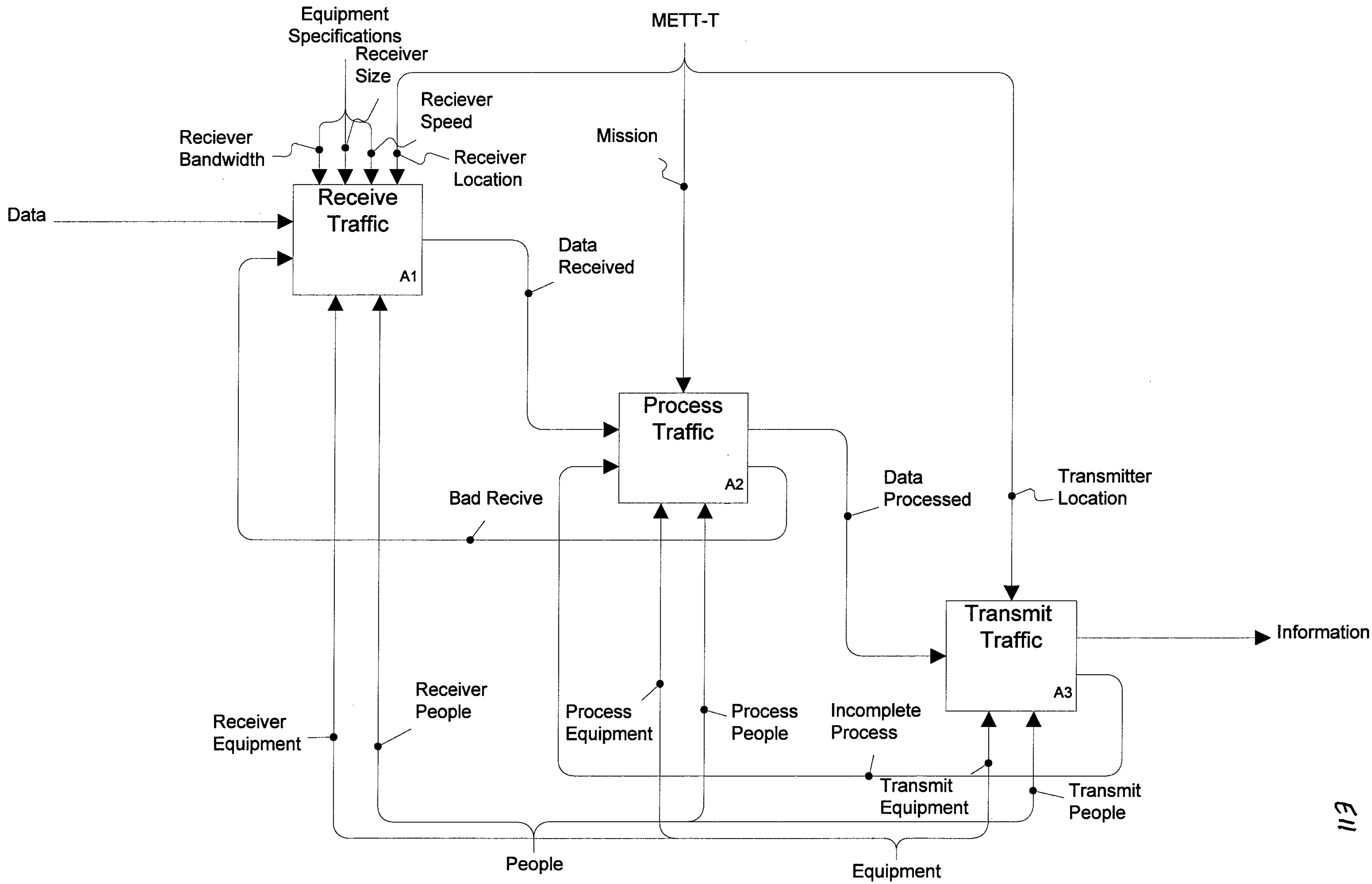
E10



PURPOSE: To identify how to support the B2C2.
VIEWPOINT: System Engineering Team

NODE: A-0	TITLE: Support B2C2 Network	NUMBER: P. 1

USED AT: [redacted]	AUTHOR: Brown, C. M. PROJECT: Support to B2C2 NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 20[redacted]96 REV: 1[redacted]	X WORKING DRAFT RECOMMENDED PUBLICATION	READER DATE [redacted]CONTEXT: [redacted]



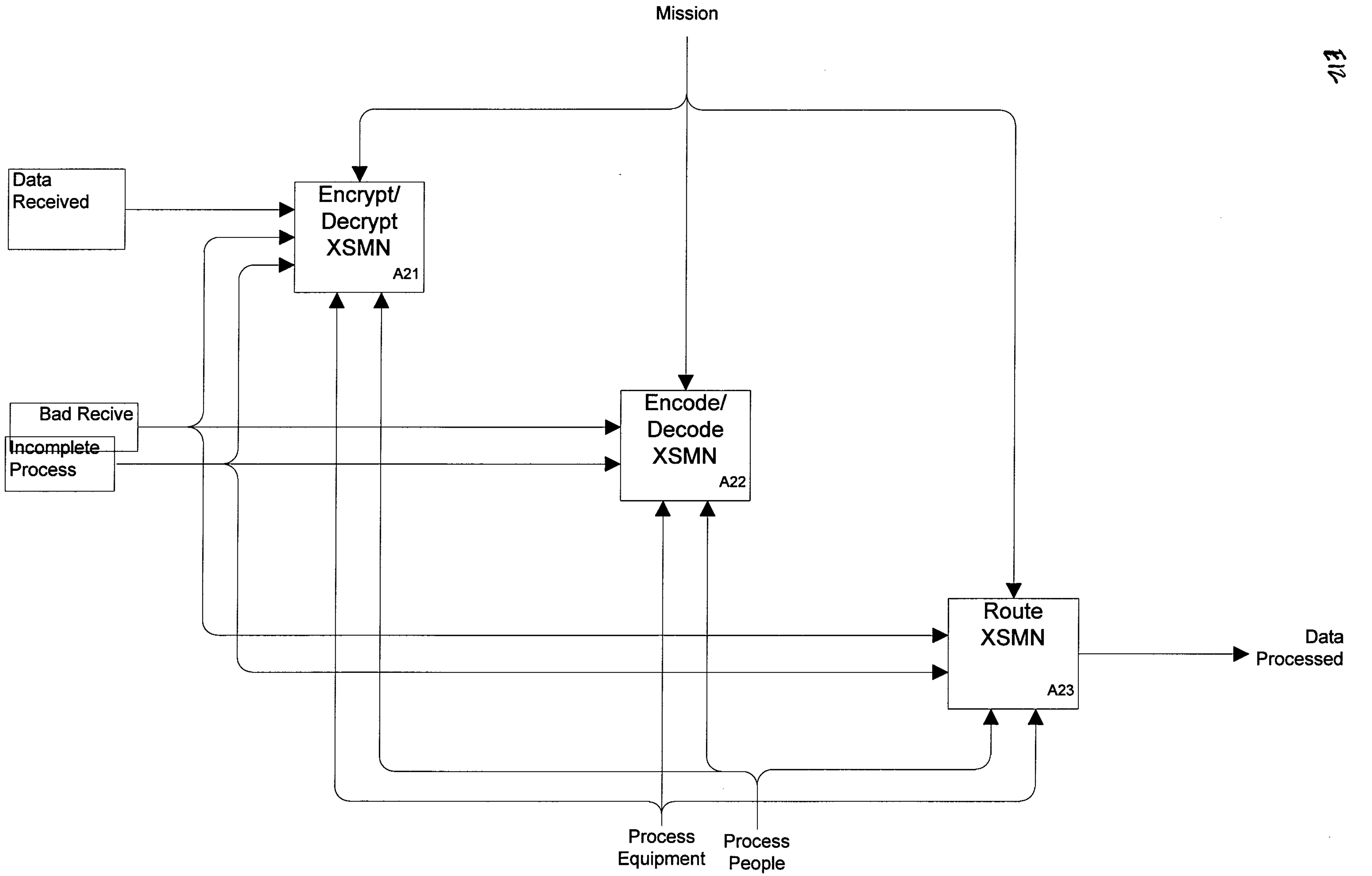
E11

NODE: A0	TITLE: Support B2C2 Network	NUMBER: P. 2

USED AT:	AUTHOR: Brown, C. M. PROJECT: Support to B2C2 NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 20[illegible]n 96 REV: 1	X WORKING DRAFT RECOMMENDED PUBLICATION

READER	DATE	CONTEXT:

E12



NODE: A2	TITLE: Process Traffic	NUMBER: P. 3

Appendix F

List of Force XXI Objectives from TRADOC Pamphlet 525-5

F2

OBJECTIVES

#	OBJECTIVE	Page 525-5
1	To be prepared to fight unconventional forces	2-5
2	To be prepared to operate against terrorism, insurgency, and partisan warfare	'
3	To exploit reserve components	3-1
4	To anticipate movement	'
5	To ensure skillful preposition	'
6	To maximize lethality	'
7	To maximize survivability	'
8	To make forces lighter	'
9	To conduct deeper operations	'
10	To anticipate possible commitments	3-2
11	To maximize use of other service assets	'
12	To use minimum force necessary	'
13	To improve joint and interagency operations	'
14	To increase joint and multi-national connectivity	'
15	To use Army HQs as efficient joint force command mechanisms	'
16	To expand linguistic knowledge and cultural awareness	'
17	TO BE TRAINED AND READY TO WIN THE LAND BATTLE	'
18	To transition from war to OOTW	'
19	To gain information and accurate and timely perceptions of the battlespace	3-3
20	To minimize cost in lives	3-4
21	To conduct a variety of missions in different operational circumstances and geographic environments	'
22	To employ both hierarchial and internetted information systems	3-5
23	To control people	3-8
24	To control terrain	'
25	To recognize/view the battlespace	'
26	To conduct simultaneous engagements by a variety of joint warfighting systems	3-9
27	To empty the battlespace	'
28	To be capable of using fires(both direct/indirect and manned/unmanned) to gain the advantage	'
29	To reduce friendly force vulnerability by increasing the dispersion and numbers of the force	'
30	To conduct maneuver by use of both fires and rapid physical mass and dispersion of ground forces	'
31	To overload the enemys ability to cope by presenting an overwhelming number of actions throughout the depth of the battlefield	3-11
32	To develop a logistics system that is versatile, deployable, and expandable	'
33	Tempo	3-19
34	To employ non-lethal, noncrippling, temporary disabling weapons and high-tech, crowd dispersal systems	3-23
35	To be versatile	4-2
36	NEED-smaller and more lethal, flexible force	4-3
37	To be prepared to make decisions, such as those concerning ROE	4-4

CDT H. Jay Brock
LTC James E. Armstrong Jr.

OBJECTIVES

F3

38	To enhance survivability and protection--LIST	4-7
39	To conduct quick, decisive, highly sophisticated, operations	4-11
40	To execute limited protracted operations against a low tech army	'
41	To know enemy operating procedures	
42	To understand enemy leaders	
43	To know the terrain	
44	To understand the people	
45	To know the culture	
46	To monitor the impact of enemy actions on the people	
47	To monitor the impact of friendly actions on the people	
48	To monitor the impact of friendly actions on enemy leaders	
49	To understand the economy	
50	To know the enemy's power or political structure	

CDT H. Jay Brock
LTC James E. Armstrong Jr.

Appendix G

List of Force XXI Terms

FORCE XXI TERMS

62

Five Characteristics

- Doctrinal Flexibility
- Stategic Mobility
- Tailorability and Modularity
- Joint, Mulitnational, and Interagency Connectivity
- Versatility in War and OOTW

Pattern of Knowledge-Based Warfare

- Plan
- Recon
- Control
- Act
- Recover

Battle Dynamics

- Battle Command
- Battlespace
- Depth and Simultaneous Attack
- Early Entry
- Combat Service Support

Force XXI Parameters

1. Battle Command based on real-time, shared, situational awareness
2. Responsibility will remain hierarchical; but organizations probably will not remain hierarchical in a traditional sense
3. Design will derive from capabilities, not from specific threat
4. May well have smaller building block...more lethal, more versatile, more effective.better
5. Force Congruence from top to bottom
6. Units will rely on electronic connectivity vice geographic or physical connectivity
7. Will be more strategically deployable with a full range of early entry capabilities tailorable to a full range of missions

Mod Thrusts

- Win the info War
- Precision Strike
- Project/Sustain the Force
- Protect the Force
- Dominate Maneuver Battle

CDT H. Jay Brock
LTC James E. Armstrong Jr.

63

FORCE XXI TERMS

Force XXI Design Principles

- The Division will be organized to optimze information-based operations
- Dominate Battlespace: speed, space, and time
- Control Battlefield tempo with overwhelming lethality and superior survivability
- Mount, execute, and recover from operations simultaneously
- Be capable of quick, decisive victory with minimum casualties
- Be rapidly deployable and operationally agile
- Enhance Tailorability through modularity across the force
- Divert tasks that inhibit the division's primary mission: to fight and win battles and engagements
- Be effective in war and OOTW as part of a joint and multinational team in all operational environments

Force XXI Constraints

Division Base
Maintain Soldier Focus
Must Change Leader-to-Led Ratio
Modular CS and CSS
Smaller Staffs
Mobile, Multi-functional command posts

Battlefield Operating Systems

Command and Control Warfare
Maneuver
Fire Support
Air Defense
Battle Command
Intelligence
Mobility and Survivability
Combat Service Support

Systems Life Cycle for Technology

Scouting
Documentation
Assessment
Selection
Tracking
Disengaging
Supporting

CDT H. Jay Brock
LTC James E. Armstrong Jr.

Appendix H

Force XXI Reference of Terms

H2

Reference Terms

Battle Dynamics (525-5)

Early Entry Lethality and Survivability

Battle Command

Mounted Battlespace

Dismounted Battlespace

Depth & Simultaneous Attack

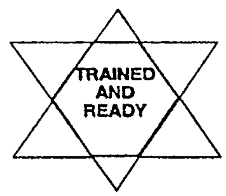
Combat Service Support

Imperatives

Quality People

Leader Development

Training



Modern Equipment

Force Mix

Doctrine

Force Modernization Objectives

- Project & Sustain
- Protect the Force
- Win the Info War
- Conduct Precision Strikes
- Dominate Maneuver Battle

Air Land Battle Tenets

(FM 100-5)

A - Agility

I - Initiate

D - Depth

S - Simultaneous

V - Versatility

Principles of War

Economy of Force

Maneuver

Mass

Objective

Security

Surprise

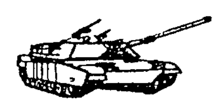
Unity of Command

Operational Patterns

- Project
- Protect
- Gain Info Dominance
- Shaping the Battlespace
- Conduct Decisive Operations
- Sustain

Battlefield Operating Systems (BOS)

- Maneuver
- Fire Support
- C^2
- Intell
- CSS
- ADA
- Mobility / Survivability



Design Principles

- Optimize Info Based Operations
- Dominate Battlespace
- Control Battlefield Tempo
- Execute/Sustain/Recover from Operations Simultaneously
- Capable of Quick/Decisive Victory with Minimal Casualties
- Rapidly Deployable & Agile
- Modular / Tailorable
- Divert tasks that inhibit Div
- Be effective in War, OOTW, Joint/Multinational Operations

Appendix I

Crosswalk of Main Ideas from 525-5 and AWEs

I-2

AWEs and Main Ideas from TRADOC Pamphlet 525-5 Crosswalk

Main Ideas from 525-5	PW/ MSF 94	DH VI 94-07	AR 94-11	TMD 95-04	PW/ MSF 95-05	FD 95-08	WF 95-11	Conclusions
1. Information technology changes how organizations, people, and leaders interact.								
2. Information technology will allow organizations to operate at levels most adversaries cannot match.								
3. Internetted and hierarchical processes will coexist.								
4. Knowledge-imposed order.								
5. Centralized and decentralized means will result in military units being capable to decide and act at a tempo enemies cannot equal.								
6. Complex forces possess greater flexibility to seize opportunities to adapt to dynamic situations.								
7. Ability to manipulate or negate portions of the electromagnetic spectrum.								
8. Protection of the electromagnetic spectrum.								
9. Battle between mechanized forces will be similar to armored operations of the past three decades.								
10. New communication systems allow the nonhierarchical dissemination of intelligence, targeting, and other data at all levels.								
11. Advances in information management and distribution will facilitate the horizontal integration of battlefield functions.								
12. Traditional hierarchical command structures will be replaced with new internetted designs.								
13. Units, key nodes, and leaders will be more widely dispersed.								
14. Substitution of situational knowledge for traditional physical control will place unprecedented demands on leaders and soldiers.								
15. Maneuver forces may be physically massed for shorter periods of time.								

Main Ideas from 525-5	PW/ MSF 94	DH VI 94-07	AR 94-11	TMD 95-04	PW/ MSF 95-05	FD 95-08	WF 95-11	Conclusions
16. Advanced forces will achieve multiple operational objectives nearly simultaneously throughout a theater of operations.								
17. Simultaneity and near-real-time military and public communications will blur and compress the traditional divisions between strategic, operational and tactical levels of war.								
18. Real-time visual images of operations will influence national will and popular support.								
19. Shared knowledge will improve deployability through smaller, more precise tailoring of combat units and support requirements.								
20. Aided by information technology, organizations will tend to grow flatter and less rigidly hierarchical.								
21. Liaison requirements will logically increase in quantity and complexity.								
22. By mastering information we can command operations at an operational tempo that no potential adversary can match.								
23. Information about the full effect of full-dimensional operations will allow greater synchronization of effort, control of tempo, and control of force application by informing units (and perhaps even enemy units to convince them to surrender).								

+ = Confirm
0 = No evidence
- = Contradict

Row of +s implies a conclusion that we have a trend of confirming evidence that the main idea is sound.
Row of -s implies a conclusion that we have experimental results which contradict the main idea therefore we may need to change the idea or discard it if we have confidence in our resutls.

NTC 94-07

Hypothesis		Results	Insights
If...	Then...		
you horizontally insert digital electronics into existing organizations using current doctrine and tactics, techniques, and procedures	You will see increases in lethality, survivability, and tempo across the force.		1.Compared to voice-only, digitization has the potential to double-to-triple the fractional exchange ratio (FER) in favor of Blue, enabling the Blue force to transition from losing (FER<1) to winning (FER>1) in NTC-like scenarios. 2.Digitization resulted in greatly increased tempo and tactical agility, resulting in a successful Blue operation and significantly increased lethality and survivability. 3.Integration of Digital Communicaitons across the combined arms can provide a significant increase in indirect fire lethality. 4.Digital equipment needs continuous reliable power source.

Task Force XXI

Hypothesis		Results	Insights
If...	Then...		
information-age battle command capabilities/connectivity exists across all BOS/functions within and to a brigade task force	significant enhancements in lethality, survivability, and tempo will be achieved.		

I-6

Warrior Focus

Hypothesis		Results	Insights
If...	Then...		
within a digitized force different technologies and doctrine are properly integrated across the force	increases in lethality, survivability, and tempo can be gained across light/heavy/SOF elements		

Battle Command

Hypothesis			
If...	Then...	Results	Insights
procedural, functional, and organizational changes in fire support, intelligence, CSS, and battle command within the task force and brigade, are made possible through Force XXI battle command	significant enhancements in lethality, survivability, and tempo will be achieved.		1.A high degree of standardization/commonality among information interfaces (icons, formats, color usage) and very user-friendly information technologies (voice-activated software, touch screens) are required to achieve efficiencies in usage and portability of experience from one information system to another. 2.The computer literacy of soldiers today is inadequate to fully implement modernized information operations and realize the full potential of digitization in Battle Command staff operations. Education and training is critical.

I-8

Focused Dispatch

Hypothesis		Results	Insights
If...	Then...		
procedural, functional, and operational changes in fire support, intelligence, CSS, and battle command within the task force and brigade, are made possible through Force XXI battle command	significant enhancements in lethality, survivability, and tempo will achieved.		

Hypothesis			
If...	Then...	Results	Insights
within a digitized force different technologies, doctrine, and organizational structures are properly integrated across the force	increases in lethality, survivability, and tempo can be gained across light/heavy/SOF elements.		

Hypothesis			
If...	Then...	Results	Insights
improvements in organization, TTP, and battle command processes accompany application of new tech. capabilities to tacitical forces,	significant increases in deployment, lethality, survivability, and tempo will be achieved.		1. 2nd GEN FLIR significantly improves force effectiveness; and digitization multiplies the effect through exploitation of the acquired information. 2. M1A2 and A3 Bradleys are sufficiently lethal and survivable that the MSF may need fewer of them in its maneuver element; HOWEVER, the impact of fewer maneuver systems on tempo, flexibility and resiliency must be assessed. 3. The MSF requires a wholly new CSS concept which leverages technology (ITV/TAV/Assured Comms). Three DOS and more trucks aren't the solution. 4. Deep fires support requires greater quantities of munitions (vice delivery systems).

Hypothesis			
If...	Then...	Results	Insights
national, joint, army capabilities are integrated into a cohesive tactical missile defense force that counters enemy across multiple phases of operations by melding attack operations, active defense, and passive defense operations together using a robust BMC31 system	then the synergy attained provides strategic level effects allowing no sanctuary for conventional and unconventional tactical and balistic missile threat operations, thereby, enhancing force Survivability and lethality while minimizing casualties		

I 12

Brigade 96

Hypothesis		Results	Insights
If...	Then...		
information-age battle command capabilities/connectivity exists across all BOS/functions within and to a brigade task force	significant increases in lethality, survivability, and tempo will be achieved.		

Appendix J

Interim Briefing Charts

J2

Department of Systems Engineering
United States Military Academy
West Point, New York 10996-1997

ORCEN

Systems Engineering Force XXI

Prepared for COL Hubbard
and Ms Diane Schuetze

Prepared by LTC James E. Armstrong Jr.

4 Oct 94

Objectives for this effort

- Organize knowledge for Force XXI decision makers.
- Establish a coherent framework and consistent terminology for Force XXI.
- Help understand past AWEs in terms of their impact on Force XXI.
- Help guide future AWEs.
- Scope and bound Force XXI.

J3

J4

Scoping Force XXI

- Effective Needs
  - A lack of something required, desired, or useful.
  - A condition requiring supply or relief.
  - Not a primitive need, it has been generalized to account for the contextual integrity of the problem and supported by evidence and logical reasons.
- Objectives.
  - Goals that stakeholders claim will add value if pursued because attaining these goals will help satisfy the needs.
- Criteria
  - A set of measures which can be used to determine success in achieving objectives.

Adapted from Sage, *Systems Engineering*, 1992, p. 79.

Effective Needs of Force XXI

- To be trained and ready to win the land battle (with fewer, more economical but more capable forces).
  - To be rapidly tailorable, rapidly expansible, strategically deployable, and effectively employable as part of a joint and multinational team to achieve decisive results in future War and OOTW in all operational environments.
  - Need to transition smoothly and quickly to OOTW.
- To conduct simultaneous operations against foes of varying capabilities.
  - To defeat multiple threats and dangers.
- To find innovative ways to apply (and combine) current and new technologies for warfighting.
- To understand nonhierarchical,internetted versus hierarchical structures
- Greater need for linguistic knowledge and cultural awareness.

J5

J6

Force XXI Objectives (1)

- To minimize cost in lives.
  - To ensure quick results.
  - To empty the battlefield.
- To minimize cost in national treasure.
  - To ensure decisive results.
  - To use the minimum force necessary.
  - To maximize survivability.

Force XXI Objectives (2)

- To have strategic staying power.
  - To control territory
    - » To extend battlespaces
  - To control people
    - » To control the electromagnetic spectrum.
  - To control events.
    - » To increase the depth, breadth, and height of the battlefield.
  - To control space.
  - To exploit reserve component capabilities.

√7

√8

Force XXI Objectives (3)

- To increase strategic mobility.
  - To increase skillful prepositioning.
  - To make forces lighter.
  - To speed up movements.
  - To reach deeper with movements.
- To increase versatility.
  - To increase tailorability and modularity.
  - To maximize doctrinal flexibility.
    - » To maximize different ways to conduct operations.

Force XXI Objectives (4)

- To fully execute full-dimensional operations.
  - To improve joint and interagency operations.
  - To increase joint and multi-national connectivity.
  - To maximize use of other services assets.
  - To facilitate use of Army headquarters as efficient joint force command mechanisms.
- To conduct multiple operations simultaneously at all levels.
  - To increase emphasis on simultaneous strikes throughout the battlespace.

J9

J10

Force XXI Objectives (5)

- To gain and share accurate and timely information.
  - To avoid operational surprise.
  - To avoid technological surprise.
- To increase lethality.
- To increase anticipation of possible commitments.

J11

Reasons for an Objectives Tree

- It represents what we are actually trying to accomplish with the design effort.
- It helps to guide the development of criteria which we will use to evaluate and compare alternative designs.
- It helps to spark the ideation of activities which will be used to generate alternatives.
- It helps to identify trade-offs that must be carefully considered.
- It reveals hidden agendas and priorities of important stakeholders.
- Rationalizes means to ends.

Five Tests of Logic

- Reading down, each objective must answer *how?*
- Reading up, each objective should answer *why?*
- Reading across under any one goal, each objective should be necessary, *extra?*
- Reading across under any one goal, the objectives should be sufficient, *enough?*
- Examine each objective, identify an owner or *stakeholder?*

Source: Adapted from Sage, Systems Engineering, 1992, p. 286.

Force XXI Success Criteria

- Warning Time for Commitments (Days)
- Number of Simultaneous Operations Controlled At Each Level (Number)
- Number of Nearly Simultaneous Attacks Throughout The Battlespace (Number of Attacks Within One Hour)
- Increase in Stand-Off Ranges for Major Weapons (Percent Increase)
- Time Elapsed From Development of Situation to Recognition of Situation (Minutes)

J13

√14

Bounding Force XXI

- System
  - A group of components that work together for a specific purpose.
  - Purposeful activity is a basic characteristic of any system.
  - Therefore, systems are designed to accomplish specific tasks or functions.
- Systems have functions.
  - A function is a specific or discrete action that is necessary to achieve a given objective.
  - For example, an operation that a system must perform to accomplish its mission, “loading a howitzer.”
  - Hint: Examine mission profile, operating modes.
  - Or a maintenance action that is necessary to return the system to operational use, “refuel, change a flat tire.”

More Bounding (1)

- Operation
  - A set of synchronized actions executed to achieve an objective.
- Process
  - A series of interdependent steps that result in a significant change.
- System
  - A group of components that work together for a specific purpose.
- Dynamic
  - Causes change over time in a system, process, or operation.

J15

J16

More Bounding (2)

- Parameters
  - Do not change much once the system is in operation.
  - Constant for each alternative design.
- Variables
  - Change within an alternative as the system operates.
- Constraints
  - Parameters may be set and variables controlled to account or compensate for constraints or limits that cannot be exceeded.

Force XXI Constraints

- Division Base
- Maintain Soldier Focus
- Must Change Leader-to-Led Ratio
- Modular CS and CSS
- Smaller Staffs
- Mobile, Multi-Functional Command Posts
- ✓ Modularity : (Smaller Units)
- ✓ Low tech – High tech mix (connectivity)
  Asymmetrical Force
- More capable platforms

J17

Force XXI Terms

- Battle Dynamics
  - Battle Command
  - Battlespace
  - Depth and Simultaneous Attack
  - Early Entry
  - Combat Service Support
- Battlefield Operating Systems
  - Command and Control Warfare
  - Maneuver
  - Fire Support
  - Air Defense
  - Battle Command
  - Intelligence
  - Mobility and Survivability
  - Combat Service Support

More Force XXI Terms

- Five Characteristics
  - Doctrinal Flexibility
  - Strategic Mobility
  - Tailorability and Modularity
  - Joint, Multinational, and Interagency Connectivity
  - Versatility in War and OOTW
- Pattern of Knowledge-Based Warfare
  - Mission Analysis and Force Tailoring
  - Reconnaissance
  - Decisive Action or Control
  - Sustained Operations or Recovery

J19

J20

Force XXI Architecture

- Functional
- Physical
- Operational
  - Scheme of arrangement or plan
  - Described by what is common or repeated in a design.
  - Identifies system, subsystems, components,and how they are grouped together. Explains their relationship to each other.
  - Identifies and defines interfaces and standards.
- Cybernetic – feedback, control & information

  integrated thought process

  team =

Force XXI Technology (1)

- Technology is the organization and application of scientific knowledge to enhance some human activity.
- A technology trend is the general direction that the enhancement of some human activity by science takes over time.
- To be a significant trend, there must be some order of magnitude of enhancement. For example, some activity must be improved, perhaps made faster or easier, by tenfold.
- Information technology is the application of scientific knowledge to help people work with data, information, and knowledge.

J21

J22

Force XXI Technology (2)

- A significant trend in technology is sometimes capable of transforming some human activity: the activity can now be done in an entirely new and different way.
- Technology extends some human or natural process.

Force XXI Technology (3)

- Systems life-cycle for technology identification, assessment, and preliminary implementation:
  - Scouting - identification of requirements specifications for candidate technologies.
  - Documentation - information about the warfighting need for and feasibility of the technologies.
  - Assessment - evaluation of the technologies.
  - Selection - of appropriate technologies for initial development and implementation.
  - Tracking - of the progress of development and implementation.
  - Disengaging - from projects that prove to be productive and that have been successfully transferred or that indicate productivity or risk potentials outside of critical bounds.
  - Supporting - the operational implementation of the technology in meaningful ways.

J23

J24

525-5 and AWEs Crosswalk

- Results and Implications
- Gaps and Trends
- Framework
- Terminology
- Future Work

Appendix K

Input to Briefing for General Franks

K2

26 Oct 94

LTC Armstrong:

1. These are the charts created from your input to COL Klevecz. He was very appreciative of your help.

2. The Army Science Board Battle Lab Issue Group will be here at Ft. Monroe on 16 Nov to meet with MG Lehowicz, COL Hubbard and the Early Entry BL. 17 Nov I'll take them to Ft Lee for an office call with MG Robison and to meet with the CSS BL. If your schedule allows, would like for you to be here on the 16th to discuss your work on 525-5 with them. Don't know yet whether Mr. Strassman will be able to make it. Will let you know.

3. Just learned last nite that I'm going to an AMC DIS Advisory Group meeting at Ft Monmouth tomorrow. I fly to Newark this evening. Had I known earlier, I might have been able to leave this morning and possibly met with you today.

Diane Schuetze

Post-it™ Fax Note 7671	Date 26 Oct	# of pages ▶ 5
To LTC Jim Armstrong	From D. Schuetze	
Co./Dept. Sys Engr	Co. HQ TRADOC	
Phone # 688-2700	Phone # 680-3712	
Fax # 688-5665	Fax # 2947	

OPERATIONS
(WARFIGHTING/TRAINING)

•1994

- ☑ LWU MUST STAY AHEAD OF FORCE XXI INITIATIVES
- ☑ SITUATIONAL AWARENESS ENHANCES "RIGHT TARGET, RIGHT TIME"
- ☑ CTC O/C EXTENSION OF LWU AND BL's
- ☑ AMT OF SENSORS IN TF OVERLOADS CURRENT FIRE SPT SYSTEMS
- ☑ EVERY SOLDIER A LDR/SENSOR
- ☑ CONFIRMED VERSATILITY AS ESSENTIAL TENET
- ☑ TAILORABILITY BASED ON METT-T REQUIRED
- ☑ LEVELS OF WAR--BLURRED
- ☑ DYNAMIC ENVIRONMENT YIELDS RAPIDLY CHANGING MILITARY STRATEGY & OPERATIONS

WHAT WE KNOW

•1995

- ☐ VALUE OF STOW AS DISTRIBUTED TRAINING AND REHEARSAL TOOL
- ☐ CHANGES IN PROCESSES/FUNCTIONS RESULTING FROM DIGITIZATION
- ☐ HOLISTIC OPERATIONAL CONCEPT FOR TMD
- ☐ IMPLICATIONS OF EXPANDED BATTLESPACE
- ☐ DTLOMS APPROACHES TO OVERCOMING DIGITAL & NON-DIGITAL CHOKEPOINTS
- ☐ MEANS TO ENHANCE EFFECTIVENESS OF FIRES

WHAT WE WILL KNOW

•1996

- ☐ INFO OPS TTP
- ☐ FORCE XXI OPNS TTP AT B2
- ☐ INITIAL• FORCE XXI DIV TTP

WHAT WE WANT TO KNOW

FORCE XXI ... JOINT VENTURE

TECHNOLOGY

1994

- ☑ DIGITIZATION ENHANCES LST
- ☑ INFO TECH IMPACTS ON CURRENT ORG/PROCESSES
- ☑ DON'T COMPLICATE WARFIGHTER'S TASKS WITHOUT > BATTLE OUTPUT
- ☑ EXCELLENCE IN TACTICAL FUNDAMENTALS GROWS IN IMPORTANCE AS TECH ARE ADDED
- ☑ IMPROVED INTEL AND INFORMATION-AGE TECH GREATLY EXPANDS BATTLESPACE

WHAT WE KNOW

1995

- ☐ DIGITIZATION OF DISMOUNTED FORCES
- ☐ VALIDATE SYNERGISTIC EFFECT OF OWN THE NIGHT AND DIGITIZATION
- ☐ OPTIMUM TMD TECHNOLOGY INVESTMENTS
- ☐ INFORMATION CONNECTIVITY ACROSS MOUNTED FORCE
- ☐ BATTLE COMMAND ENHANCEMENTS FOR CDR/STAFF
- ☐ TACTICAL CONNECTIVITY WITHIN DIVISION
- ☐ LST ENHANCEMENTS RESULTING FROM SELECTED 2010 CAPABILITIES

WHAT WE WILL KNOW

1996

- ☐ IMPACT OF FBCB2 HARDWARE/SOFTWARE
- ☐ VALUE ADDED OF OTHER SELECTED TECHNOLOGIES
- ☐ INTEGRATION OF TECHNOLOGIES INTO BRIGADE AND BELOW
- ☐ INSIGHTS INTO TECHNOLOGY REQUIRED FOR FORCE XXI DIVISIONS

WHAT WE WANT TO KNOW

FORCE XXI ... JOINT VENTURE

K5

EXPERIMENTS

•1994

- ☑ CAN TRAIN, TEST & EXP SIMULTANEOUSLY
- ☑ TRAIN TO STANDARD BEFORE EXPERIMENTING
- ☑ EARLY ANALYTIC INVOLVEMENT
- ☑ DEFINED BASELINE
- ☑ IMMEDIATE OPNL UTILITY OF EXP OUTPUT
- ☑ FAILURE IN EXP NOT NEC BAD
- ☑ CONSERVATIVE EXP CANNOT LEAD TO BOLD CHANGE
- ☑ SIMULATIONS/SIMULATORS CRITICAL TO FORCE XXI
- ☑ GICOD REQ'D
- ☑ DISCIPLINE REQUIRED TO FOCUS ISSUES AND LIMIT COST

•WHAT WE KNOW

•1995

- ☐ SYNERGISTIC EFFECT OF LINKING AWEs (INTEL & PHYSICAL)
- ☐ VALUE OF HOLISTIC ANALYTICAL APPROACH
- ☐ MODEL/SIMULATION OF DISMTD FORCES
- ☐ REFINE/EXPAND CONFEDERATION OF MODELS
- ☐ VALUE OF STOW AS ANALYTICAL TOOL

•WHAT WE WILL KNOW

•1996

- ☐ MUST DEVELOP STOW CAPABILITY THRU DIVISION-LEVEL
- ☐ DEVELOP SIMULATION CAPABILITY FOR INFO OPN
  - •- COMMUNICATIONS
  - •- C2W
  - •- RISTA

•WHAT WE WANT TO KNOW

FORCE XXI ... JOINT VENTURE

ORGANIZATION

1994

- ☑ TO FULLY OPTIMIZE LST FOR EARLY ENTRY, MUST NOT ONLY INFUSE NEW TECHNOLOGY, BUT ALSO ADJUST ORGANIZATIONS
- ☑ ABSOLUTE REQUIREMENT TO DESIGN CSS FORCES CONCURRENT WITH CA, CS
- ☑ FORCE ARTY HQ ESSENTIAL
- ☑ VALUE ADDED OF DOCC/ACE FOR FULL- DIMENSIONAL OPS

WHAT WE KNOW

1995

- ☐ COMBINATIONS OF CA, CS, CSS THAT OPTIMIZES LST ACROSS EXPANDED DIV BATTLESPACE
- ☐ TF ORG DESIGN TO OPTIMIZE FIRES, INTEL, CSS, AND BATTLE COMMAND
- ☐ INCREASES TO EARLY ENTRY LST THROUGH ORGANIZATIONAL DESIGN
- ☐ OPTIMAL ORGANIZATION FOR EFFECTIVE TMD

WHAT WE WILL KNOW

1996

- ☐ MEANS TO EXECUTE MODULARITY ACROSS CA, CS, CSS
- ☐ INTERIM FORCE XXI DIVISION DESIGN
- ☐ OPTIMUM BRIGADE ORGANIZATION

WHAT WE WANT TO KNOW

FORCE XXI ... JOINT VENTURE

What Do We Know Now? (1)

- Multiple payoffs across the force from improving shared situational awareness.
- Assured, mobile comms, linkages, and connectivity among collectors, processors, commanders, and shooters are key enablers for future operations.
- Mobile, survivable platforms with stand-off, multi-salvo, fire-and-forget, smart munitions are big killers and give commanders the ability to mass effects (but these could be virtual (aka distributed) platforms in the future.

pulsing } MSF

K7

K8

What Do We Know Now? (2)

- **Potential for much leaner and better CSS by improvements in automation, information, mobility, and survivability.**
- **Training and education of soldiers and leaders needs improvement in both focus and direction to successfully execute Force XXI operations.**
- **Tactical Ballistic Missiles (TBMs) still are potential show stopper especially early on.**

Dimension of size at the tactical level

What will we know after we complete our AWEs? (1)

- PW/MSF
  - Are major changes to organization and TTP possible or desirable in light of improved battle command processes and new technological capabilities. How much can we change?
- WARRIOR FOCUS
  - Nothing much new to learn except can learn better how digitization may cause or facilitate changes to doctrine and organization.
- TMD 95
  - Will learn how far we have progressed in providing protection for the force from a potential showstopper from the NCA viewpoint.

K9

K10

What will we know after we complete our AWEs? (2)

- FOCUSED DISPATCH
  - Lots new to learn here. This should get to the "Right Target, Right Time" issue. Can we unscramble our CP/TOC/TAC procedures and staff processes so that commanders can better recognize and understand situations, better formulate and disseminate plans, and better execute and monitor combat operations.
- ATLANTIC RESOLVE
  - Lots to learn here. We should begin to know how far we have come to being able to fully execute full-dimensional operations. For example, we should learn how to facilitate the use of an Army HQs as an efficient joint force command mechanism. Also, how to improve joint, interagency, and multi-national operations.

What will we still not know in a year? (1)

- **We will know very little about information operations.**
  - For example, how will we manipulate, isolate, or negate portions of the electromagnetic spectrum? What level of command will be able to execute or request such info. operations? How should these information operations be synchronized with other more traditional operations.
- **We will know very little more about OOTW except for operational experience from Haiti.**
  - In complex political-military environments like the one in Somalia that spawned TF Ranger, we will not have a training center to replicate undeveloped urban regions with hostile and peaceful populations intermixed.

Objective

Well-founded in theoretical and principle

theory and principle

qualitative

Review principles of war

117

K12

What will we still not know in a year? (2)

- Which traditional hierarchical command structures can be replaced by internetted designs.
- How situational knowledge can substitute for traditional physical controls.
- How flat we can make our organizations.
- How far units, key nodes, and leaders can be dispersed.
- What new and unprecedented demands will be placed on leaders and soldiers.

What will we still not know in a year? (3)

- How robust are our forces in terms of understanding how different potential enemies may adopt different operating procedures and mechanisms which may cause difficulties for high technology forces.
- How many simultaneous operations can be conducted at all levels or echelons.
- How present and future public communications such as Project Iridium and Teledesic will impact military operations.

K13

Appendix L

Task Force Ranger Cadet Worksheets

L2

SE401 Design Exercise Lab #1
Requirements

Names INSTRUCTORS

{ SOME CADETS }

Section SE 401

Joint Special Operations

PART I

1. (2 points) Considering that a system is a group of elements that work together for a specified purpose, identify the system under consideration?

75 th RANGER REGIMENT

2. Considering the "Systems Point of View," answer the following:

(a) (2 points) What is the **purpose** of the system identified above?

To accomplish assigned special military operations missions successfully.

(b) (2 points) To achieve the purpose of the system, a number of functions must be implemented. These functions, or purposeful actions, are basic characteristics of the system. Identify two major functions that will achieve the purpose of the system identified above.

Planning

Fighting

Training

(c) (3 points) Considering the functions you identified in (2) above, list only three operating components of the system. Why are they operating components?

Leaders - They make the plans, lead the fight, and conduct the training.

Ranger Soldiers - They execute the plans, do the fighting.

Support Elements - They support training and fighting by repairing equipment, providing supplies.

(d) (3 points) Considering the functions you identified in (2) above, list only three flow components of the system. Why are they flow components?

People - Go thru training, take positions, fight and may be casualties.

Information or Intelligence - Decisions, Orders, (FRAGOs), Estimates are all forms of information that get disseminated. Controls the fighting.

Enemy Soldiers - Are engaged or captured.

(e) (3 points) Considering the functions you identified in (2) above, list only three structural components of the system. Why are they structural components?

Chain of Command

MTOE (Unit Equipment)

Unit SOP (Standard Operating Procedures)

Once the mission begins, these do not change much.

L3

DE Lab #1

951

(f) (2 points) The structure of a system identifies the relationship between its components. It is hierarchical in nature and can be defined in terms of other components or subsystems. What is a super-system of the system you identified? Why?

Joint Special Operations Command - in charge of Task Force Ranger

(g) (2 points) What is a lateral system of the system you identified? Why?

Delta Force fought alongside the Rangers.

(h) (3 points) What are three subsystems of the system you identified? Why?

S1 - Personnel Subsystem - Care and replacement of casualties.
S2 - Intelligence Subsystem - gather and disseminate info.
S3 - Operations Subsystem - plan and control the fight.
S4 - Supply Subsystem - provide and distribute supplies.

3. (3 points) Identify the primitive need(s) and state it in clear and concise words below. Cite the source of your primitive need.

"Redesign the Rangers" - COS

"Beef-up the Rangers" - "

"Catch-up with technology" "

4. (5 points) List at least five stakeholders below:

Stakeholders

President
Chief of Staff, US Army - GEN Nijmegen
Deputy Chief of Staff for Operations - M
Ranger Regimental Commander
Congress
Ranger Soldiers
American Public ...and more.

L4

PART II

TURN IN BOTH PART I AND PART II AT THE BEGINNING OF LESSON 10.

5. (8 Points) Which of those you listed in 4 above are the ?

Decision Maker(s)? — Why?

President → NCA, Cdr in Chief decides ultimately if mission is a "Go."

Chief of Staff US Army → Makes decision on redesign of Rangers.

Client(s) — Why?

DCSOPS — He is tasking the design team and is responsible for providing answers to the chief.

Analyst — Why?

CADET DESIGN TEAM — We are doing the work

Other — Why?

American Public — Bill payers.

Congress — Control $s.

6. (7 points) Generalize the primitive need into an effective need(s) by considering the stakeholders. State the effective need below clearly and concisely, ensure you cite specific evidence to support your statement.

Examine the current design of the Ranger Regiment, determine if they are organized, equipped, trained, ~~and~~ supported, and led so that they can successfully perform future missions. (Chief's memo, p.6,7) The Rangers C3I capabilities, particularly situational awareness and intelligence

7. (10 points) The stakeholders would like to achieve many objectives to support and satisfy their needs. After considering the stakeholders, list five major **objectives that will satisfy the effective need(s).** Make sure you identify which stakeholder is concerned with each specified objective. (Somali capabilities grossly underestimated) -RPG barrages at chopper -Reaction time, barriers.

~~Objective~~ ~~Stakeholder~~

must be improved. Further the Rangers need to be better prepared to fight urban warfare in Third World Countries and to engage in (OOTW) operations other than war in underdeveloped urban ~~nations~~ terrain.

Objective	Stakeholders
Max mission accomplishment	Ranger Regimental Cdr.
Min costs	Congress
Min casualties	President
Max training	Ranger Soldiers

45

8. (15 points) Construct a thorough Input/Output Model for the operations phase of the system you identified. Place your work in the space below. Be sure to explain ~~the process~~ (i.e., what is being transformed) and place your answer in the box provided below. Include all inputs and outputs that relate to the system and clearly identify them below. Only identify four controllable inputs, four uncontrollable inputs, one intended output and four by-products.

CONTROLLABLE INPUTS

- TRAINING
- ORDERS TO SUBORDINATE ELEMENTS
- TASK ORGANIZATION
- EQUIPMENT
- SOPs
- SUPPLIES

PROCESS

RANGER COMBAT OPERATIONS

INTENDED OUTPUT

- SUCCESSFULLY ACCOMPLISHED MISSION(S)

UNCONTROLLABLE INPUTS

- ★ MISSION(S) FROM HIGHER HQs
- ENEMY
- TERRAIN
- TIME AVAILABLE
- INTELL FROM EXTERNAL SOURCES

BYPRODUCTS

- ENEMY & FRIENDLY CASUALTIES
- ENEMY REACTIONS
- LOST & DAMAGED EQUIPMENT
- GOOD & BAD PRESS REPORTS
- BETTER OR WORSE ARMY MORAL
- NATIONAL PRIDE & SECURITY
- PUBLIC TRUST & CONFIDENCE IN LEADERS INCREASED OR DECREASED

46

DE Lab #1
951

9. (5 points) The Chief of Staff has to testify before Congress about this issue. Based on your design work **to this point**, what assessment could you give to DCSOPS? (at this point, "What is the Bottom Line?")

(a) Should we consider redesigning the 75th Ranger Regiment? Why? Yes,* because the Task Force Ranger mission in Somalia was costly (18 killed, 100 wounded) and resulted in the exit of all US forces and the evaporation of American resolve. Also, the Rangers will likely be called on to do similar operations in the future (Haiti?)

(b) Should we "beef up" the Rangers? Why?

Yes,** since the Rangers will find themselves in more operations like Somali, they need a way to fight through barriers if necessary and to survive if temporarily isolated in a hostile environment. They must be more survivable while being stealthy!

(c) Should we give the Rangers different types of missions? Why?

No, Rangers successfully accomplished the mission except for a quick safe exit. Had they had adequate intelligence, the operation may have been a big success

(d) Do the Rangers need other support to be combat effective (i.e. more armor)? Why?

Yes, the Rangers need to habitually practice task organizing with Delta Force, Intelligence Agencies and Army reaction force units to overcome the coordination problems that prohibited adequate, responsive support in Somalia.

(e) Is the Ranger's command, control, communications and intelligence adequate (C3I)? Why?

Often failures occur in a system because of interface problems with other systems or due to faulty interactions among subsystems or their component parts. In special operations, particularly 'leader snatch' type missions, intelligence that is timely and accurate is crucial. The intelligence subsystem of TF Ranger was depending heavily on a dedicated interface to one specific, external human intelligence source. That interface broke down when the HUMINT source shot himself in the head. Another indicator of problems with the intelligence subsystem is the under estimation of the enemy threat by TF Ranger. Apparently the planners of the operation did not anticipate two important enemy capabilities. First, the enemy's command and control system, although technologically simple, walkie talkies & sector commanders, was very effective at quickly mobilizing many

* Cadets could also answer "No" and say we don't know enough about why the mission failed to say definitely that the Rangers need to be redesigned. Other cadet answers that offer logical explanations and cite specific evidence are acceptable.

(over)

** Cadets could also answer "No" and explain why more is not necessarily better and point to other reasons why the mission failed, such as intelligence. Intell had not 'seen' Aideed for a month before the op.

Place all documentation necessary in the space provided below:

armed Somali's into the fight and in coordinating the erection of barriers covered by fire. Second, planners did not foresee that the enemy would organize coordinated barrages of RPG fire to bring down the helicopters. Also, intell. sources, external to TF Ranger, had not been able to locate Aideed for an entire month prior to the operation.

Of course this analysis is based on press and other open sources. Actual happenings may be somewhat different but are classified. We do know the Rangers fought heroically.

48

DE Lab #1
951

SUPER ANSWERS TO TOUGH QUESTIONS

9. (5 points) The Chief of Staff has to testify before Congress about this issue. Based on your design work **to this point**, what assessment could you give to DCSOPS? (at this point, "What is the Bottom Line?")

✓ (a) Should we consider redesigning the 75th Ranger Regiment? Why?

Yes, Operation Restore Hope in Somalia was a costly & embarossing defeat of one of the U.S.'s most elite units by a band of hoodlums. 18 Americans were killed & 80 injured. This was a failure that demands Ranger redesign.

(b) Should we "beef up" the Rangers? Why?

Yes. As we move from a bi-polar to a multipolar world we will find ourselves in more conflicts like this. The Rangers need all the equipment necessary to defeat an enemy armed with anti-armor weapons. The Rangers must become "armored," but maintain their stealth.

Need more [illegible]

(c) Should we give the Rangers different types of missions? Why?

These type of missions are ideal for the Rangers. No one will be able to do them better. The Rangers need to spend more time training for urban warfare. Perhaps an urban phase should be added to Ranger school & their NTC rotation.

(d) Do the Rangers need other support to be combat effective (i.e. more armor) ? Why?

The Rangers must have M1A2 Abrams & M2 & M3 Bradleys organic in their units when conducting this sort of mission. It is too late to request them once the battle has started.

(e) Is the Ranger's command, control, communications and intelligence adequate (C3I) ? Why?

No, the nature of the Rangers' mission demands better C^3I. It is unacceptable to have your HUMINT not o[illegible]ght and to not know the location of your primary target for almost a month. The Rangers usually operate with other units like the 10th MTN DIV & Delta Force. This makes C^3I all the more difficult, but all the more important. The Rangers can improve their C^3I by consolidating all resources they need for this type of mission into the Regiment. The less the Rangers must rely on other units, the better their command, control, & communications will be. Rick Atkinson's The Raid That Went Wrong says, "Despite the intelligence shortcomings, Task Force Ranger threw itself into the [illegible] at hand." This is unacceptable. Such elite, important missions should never operate under such poor intelligence. In addition, a consolidation of this type of mission solely under the Ranger will avoid two two-star generals being coequals in a mission. Garrison & Montgomery got along, but typically two generals will clash in such a stressful environment.

Appendix M

Tutorial on Building IDEF0 Activity Models

(Prepared by CPT Jeff Joles, edited by LTC J. E. Armstrong, D/SE, USMA, West Point, NY)

TITLE: Synthesis of Alternatives - Reengineering Processes

LESSON OBJECTIVES:

1. Understand what reengineering is and why it is important to systems engineers.

2. Understand the fundamentals of IDEF0 as a modeling technique.

3. Describe the essential components and structure of an IDEF0 model, to include context diagrams, node tree diagrams, and decomposition diagrams.

4. Understand the use of ICOMs to define relationships between activities.

5. Model a process using IDEF0 methodology.

STUDY ASSIGNMENT:

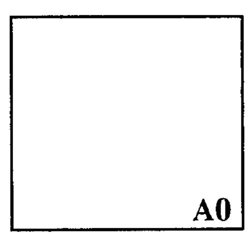
READ: Course Notes, pages 1-3 through 1-8

DRILL PROBLEMS:

1. Define the terms: *Activity, Input, Output, Control, Mechanism* as they apply to IDEF0 models and give an example of each.

2. Given the activity and ICOMs below, build an appropriate IDEF0 context diagram. You may add additional ICOMs if desired.

Activity: Conduct a Needs Analysis



ICOMs:

Environment	Information
Primitive Need	Analyst
Effective Need	Objectivity
Stakeholders (Objectives)	Top-Level Objectives

3. Given the following node tree, develop an IDEF0 decomposition diagram for the activity, (A0) Sell Pizza, using the seller's perspective. Include and label appropriate ICOMs.

(A0) Sell Pizza
(A1) Enter Order
(A11) Accept Order Information
(A12) Compute and Quote Price
(A13) Generate Order Form
(A2) Process Order
(A21) Assemble Pizza
(A22) Cook Pizza
(A23) Package Cooked Pizza
(A3) Deliver Pizza
(A31) Delivery Person Takes Pizza
(A32) Transport Pizza to Customer
(A33) Document Delivery

4. Consider the process of writing a research paper on an assigned topic. Using the cadet perspective, develop an IDEF0 context diagram for the process and prepare a decomposition diagram for the top level activity. Include and label appropriate ICOMs.

SYNTHESIS OF ALTERNATIVES

REENGINEERING PROCESSES

WHAT IS REENGINEERING?

In recent years, reengineering has been a "buzzword" in the business community. It has been touted as a method of revitalizing US industries that are in financial difficulty, as a technique that can be used to improve the efficiency of an organization, and as a way for a firm to lower costs or raise productivity. It is important for systems engineers to have an understanding of what reengineering is and how it is accomplished because the concept allows a reengineering team to evaluate an existing process and search for ways to restructure it and significantly improve mission performance. As systems engineers, you will be called upon to evaluate existing processes and make recommendations for improvement. The concept of reengineering will help you perform this analysis.

So, what exactly is reengineering? One useful definition is: "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service, and speed." [1] Applied in a broader perspective, during reengineering an organization undergoes some detailed introspection, evaluates what its objectives are, performs a functional decomposition of its activities, and determines what needs to be done in order to best meet the organization's objectives. In effect, the organization is redesigned from the ground up. The current reengineering of U.S. Army Forces Command (FORSCOM) to meet the challenges of the 21st century is a good example. Posturing FORSCOM to support Force XXI, the Army of the 21st century, has entailed an in-depth look at what FORSCOM does and how it accomplishes its mission. The result of this massive undertaking has been new ways of doing the business of keeping a power-projection Army trained and ready in a shrinking resource environment. [2]

Reengineering efforts parallel the systems engineering design process, except that it is now being used to improve an existing system, rather than design a new one. One useful technique when reengineering processes (or developing new ones) is function modeling because it not only identifies key activities (functions), but also establishes relationships between activities. A well constructed function model is critical to integrated systems planning/design since all components and relationships are shown. IDEF, short for Integrated Definition, [3] is a function model paradigm sometimes used in reengineering and design activities.

IDEF

In the 1970's, the United States Air Force recognized the need for a function modeling methodology as a result of the Integrated Computer Aided Manufacturing (ICAM) program. One of the original IDEF (ICAM DEFinition) methods was IDEF0 (pronounced Eye-DEF Zero). IDEF0 is a static modeling paradigm that depicts a system as a network of interconnected activities performing controlled transformation of inputs into outputs using mechanisms. Additional IDEF models have since evolved to meet other business needs, including IDEF1, IDEF1X, IDEF2, IDEF 3, and IDEF4. [4] For simple systems, all the analyst needs to build an IDEF0 model is a stubby pencil and some paper. Computer applications are generally needed to build more complex models.

REENGINEERING AND IDEF0 [5]

IDEF0 methodology allows the systems engineer to model the decisions, actions, and activities of a system or organization. It is another analysis technique for establishing the scope of analysis and determining which functions in a system are performed well, and those which should be improved. In organizing the analysis of a system, effective IDEF0 models promote good communications about the functional perspective of the system between the analyst and the client. Because of this analyst-client link, IDEF0 models are often created early in the systems analysis process.

Using IDEF0, activities can be organized and the relation between activities graphically represented. Activities are described by their *inputs, outputs, controls, and mechanisms.* Each activity can also be decomposed to provide greater activity detail until the model is as descriptive as needed.

The hierarchical nature of IDEF0 allows the analyst to construct models of existing systems (AS-IS models) which have a top-down representation and interpretation but which are based on a bottom-up analysis process. Beginning with raw system data (generally obtained through client interviews), activities that are closely related or similar in function are grouped together. The system hierarchy emerges through this grouping process which can be applied until the highest-level activity has been described. If a system's functional architecture is being designed (TO-BE modeling), top-down construction is normally used. Beginning with the top-most activity, the system under design is described using functional decomposition until the desired level of detail is achieved.

IDEF0 COMPONENTS AND STRUCTURE

The IDEF0 model describes a system by its functions or activities. *Activities* are functions, processes, or tasks that use mechanisms to transform inputs into outputs as directed by controls. *Inputs, Controls, Outputs, and Mechanisms* are referred to as *ICOMs*.

ICOMs [6]

Input - something that is transformed by an activity. Some examples of inputs are raw materials, information, client need, etc. Inputs are represented by an arrow entering the activity box from the left.

Control - something that determines how or when an activity occurs, but is not transformed by it. Examples of controls include regulations, policies, objectives, etc. Controls are represented by an arrow entering the activity box from the top.

Output - something that is produced by or results from an activity. Examples of outputs are products, data, transformed materials, etc. Outputs must include the input in some form. Outputs are represented by an arrow exiting the activity box from the right.

Mechanism - resources (people, facilities, machines, systems) that provide energy to or perform the activity. Some examples of mechanisms are equipment, an analyst, computer system, etc. Mechanisms are represented by an arrow entering the activity box from the bottom.

The IDEF0 model represents a system as activities that use ICOMs to accomplish tasks. When an activity uses an ICOM, the IDEF0 model shows the use by attaching the ICOM's arrow to the affected activity box as depicted in the basic IDEF model in Figure 11-1. An activity box may have any number of ICOMs of any type.

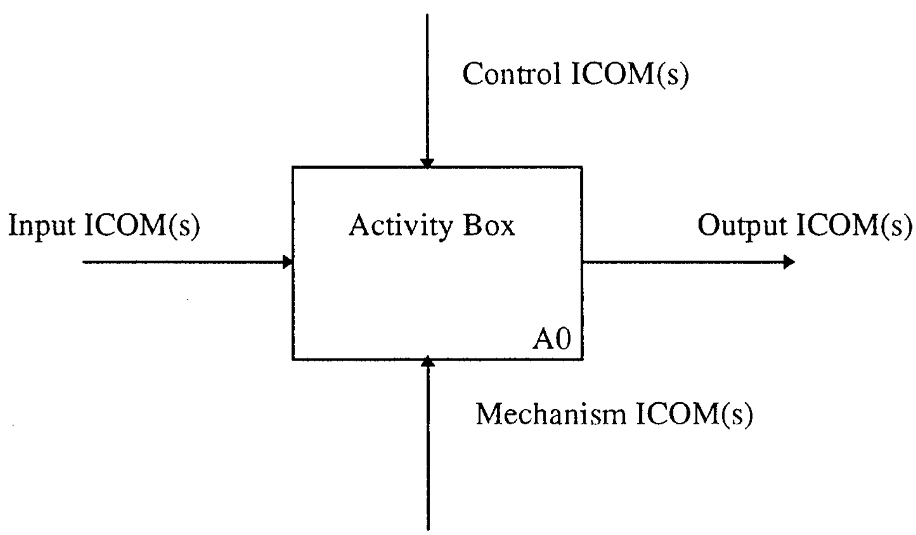


Figure 1-1. Basic IDEF Model.

Labels

In addition to identifying an ICOM by its position relative to the activity box, each ICOM arrow must have a label to identify what it is. The following rules apply to IDEF labeling of activities and ICOMs.

> **Activities** are ALWAYS labeled with a verb or verb phrase; conduct analysis, plan party, manufacture part, etc.
>
> **ICOMs** are ALWAYS labeled with a noun or noun phrase.

For example, the IDEF0 context diagram for Figure 11-1 might look like this for the activity, Fire M-16.

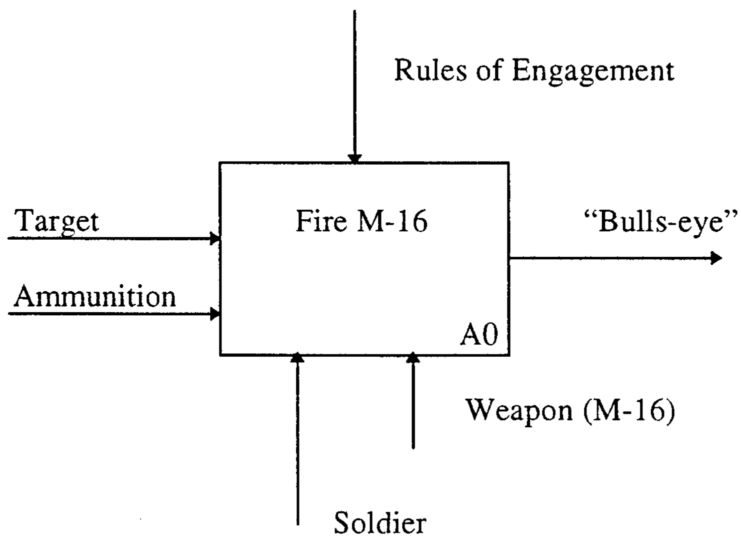


Figure 1-2. Context Diagram, Fire M-16.

Context Diagrams

A context diagram is the single IDEF0 activity representing the system and its interface with the outside world. This diagram shows the context within which the model exists and includes only those features relevant to the model's purpose. Figure 11-2 is one possible context diagram for the activity, Fire M-16. Note that the activity box is labeled A0 indicating that it is the context diagram in the model's hierarchical structure.

Node Tree Diagrams

Similar to objective or criteria diagrams, node trees are useful for defining large complex models without ICOMs. Each node of the tree is a function or activity whose node number corresponds to an activity box in the IDEF0 model's hierarchy. Similar to the outline used by a writer, node trees are often useful in outlining the system before developing an IDEF model.

A node tree for the context diagram in Figure 11-2 might look like the representation below where the designations preceding each activity indicates a node. Note that ICOMs are not shown on the node diagram.

(A0) Fire M-16
- (A1) Prepare to Fire
  - (A11) Assume Position
  - (A12) Load Weapon
- (A2) Acquire Target
  - (A21) Sight Target
  - (A22) Determine Range
- (A3) Squeeze Trigger
  - (A31) Steady Weapon
  - (A32) Apply Trigger Pressure

Graphically, the same diagram might be portrayed as below:

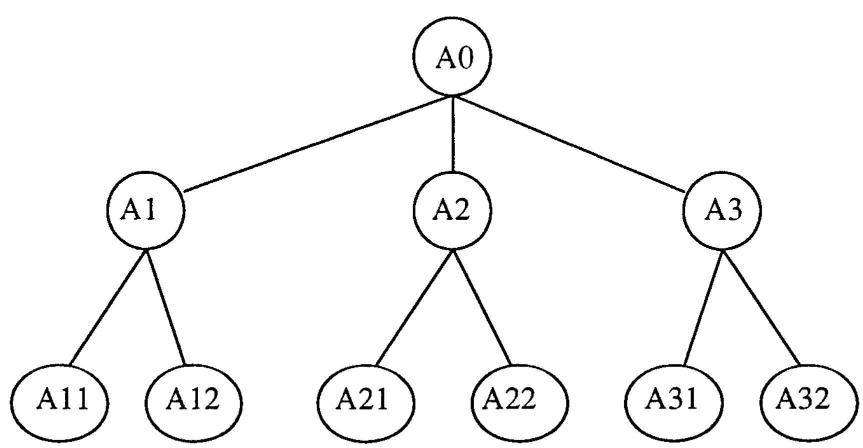


Figure 1-3. Node Tree Diagram.

Decomposition Diagrams

Activity boxes can be depicted in more detailed, lower level diagrams representing those activities comprising a "parent" activity. [7] In Figure 11-3 above, activity A1 is the "parent" of activities A11 and A12,. Once again using the previous node tree to describe the activity, Fire M-16, the decomposition of the context diagram (Figure 11-2) might look like Figure 11-4. **NOTE:** An output from one activity may become an input, control, or mechanism for another activity. To highlight the concept of decomposition diagrams, only the context diagram's ICOMs are included in Figure 11-4 . Normally, all appropriate ICOMs would be labeled.

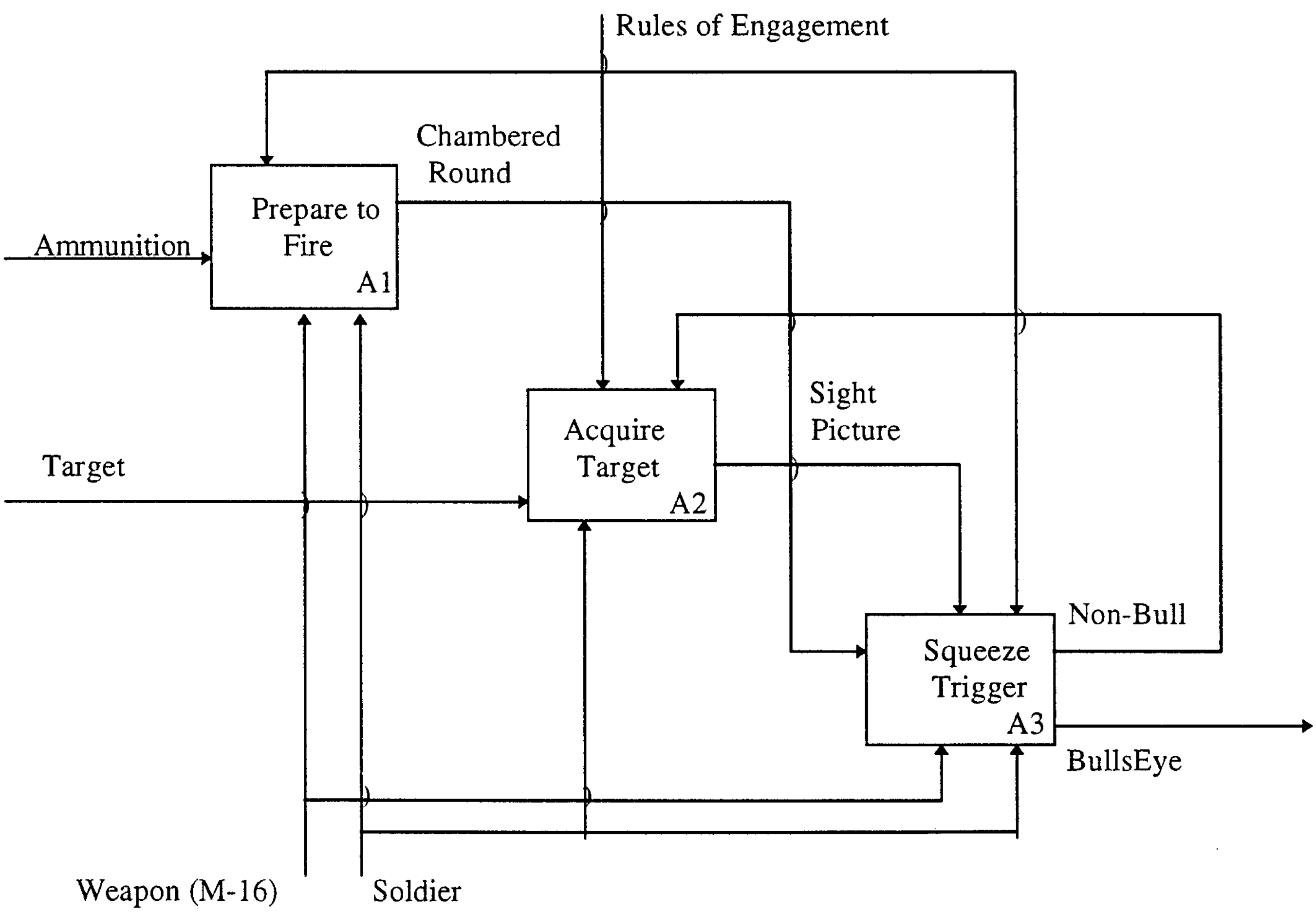


Figure 1-4. Decomposition Diagram, Fire M-16.

SUMMARY

Reengineering is a fact of life as organizations strive to improve efficiency. IDEF functional modeling is a useful technique available to systems engineers in redesigning existing systems and designing new ones.

NOTES

[1] Michael Hammer and James Champy, *Reengineering the Corporation*, (New York: 1993) 32.

[2] General Dennis J. Reimer, "Reengineering Forces Command for the 21st Century," Army May 1995: 31-34.

[3] D. Appleton Company, Inc., *Corporate Information Management Process Improvement Methodology for DoD Functional Managers*, (Fairfax, VA: 1993) 158.

[4] Knowledge Based Systems, Inc., *AI0 WIN User's Manual and Reference Guide*, (College Station, TX: 1993) 1-6.

[5] Knowledge Based Systems, Inc., 1-7.

[6] Meta Software Corporation, *Design/IDEF Tutorial for Microsoft Windows*, (Cambridge, MA: 1995) 4-3 to 4-5.

[7] Meta Software Corporation, 4-10.

REFERENCES

Marca, David A., and Clement L. McGowan. IDEF0/SADT Business Process and Enterprise Modeling, Eclectic Solutions, San Diego CA, 1993.

Lesson Title: Synthesis of Alternatives: Activity Modeling

Lesson Objectives:

1. Apply Activity Based Costing (ABC) to an IDEF model and determine the value added for specific activities.

2. Given an IDEF activity model, create reengineering alternatives.

Study Assignment:

Read: Course Notes, pages 2-5 through 2-14.

Read: Supplemental Reading, Extract from Reengineering the Corporation by Michael Hammer and James Champy.

Drill Problems:

1. You are the owner of a small pizza shop. As part of a business analysis, you perform an IDEF decomposition of the activity "Sell Pizza". Now you want to apply ABC to determine all of your activity costs. Fill in the missing activity based costs in the IDEF model on the following four pages. What is the cost of the A0 activity "Sell Pizza"?

Note: You have determined that to "assemble pizza" costs you:

Direct Labor: $0.70
Indirect Labor: $0.35
Cost of Goods: $2.10
Supplies: $0.20
Overhead: $0.30

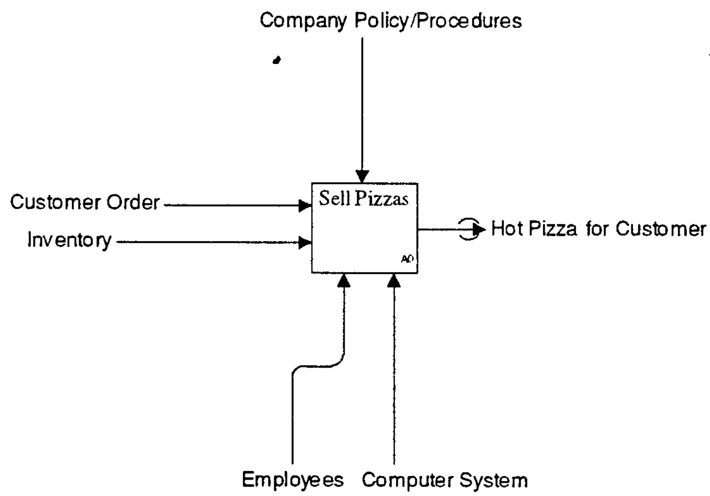
2. Think of a system that you consider broken; one that is not meeting customer needs. Describe, in the terms of this lesson, what problems there are with the system. How might you apply reengineering techniques to the system in order to improve it?

Drill Problem #1 (continued):

USED AT: SE 401	AUTHOR: USMA Cadet PROJECT: Pizza Shop NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 04/23/95 REV: 1	x	WORKING	READER DATE	CONTEXT: Top
				DRAFT		
				RECOMMENDED		
				PUBLICATION		

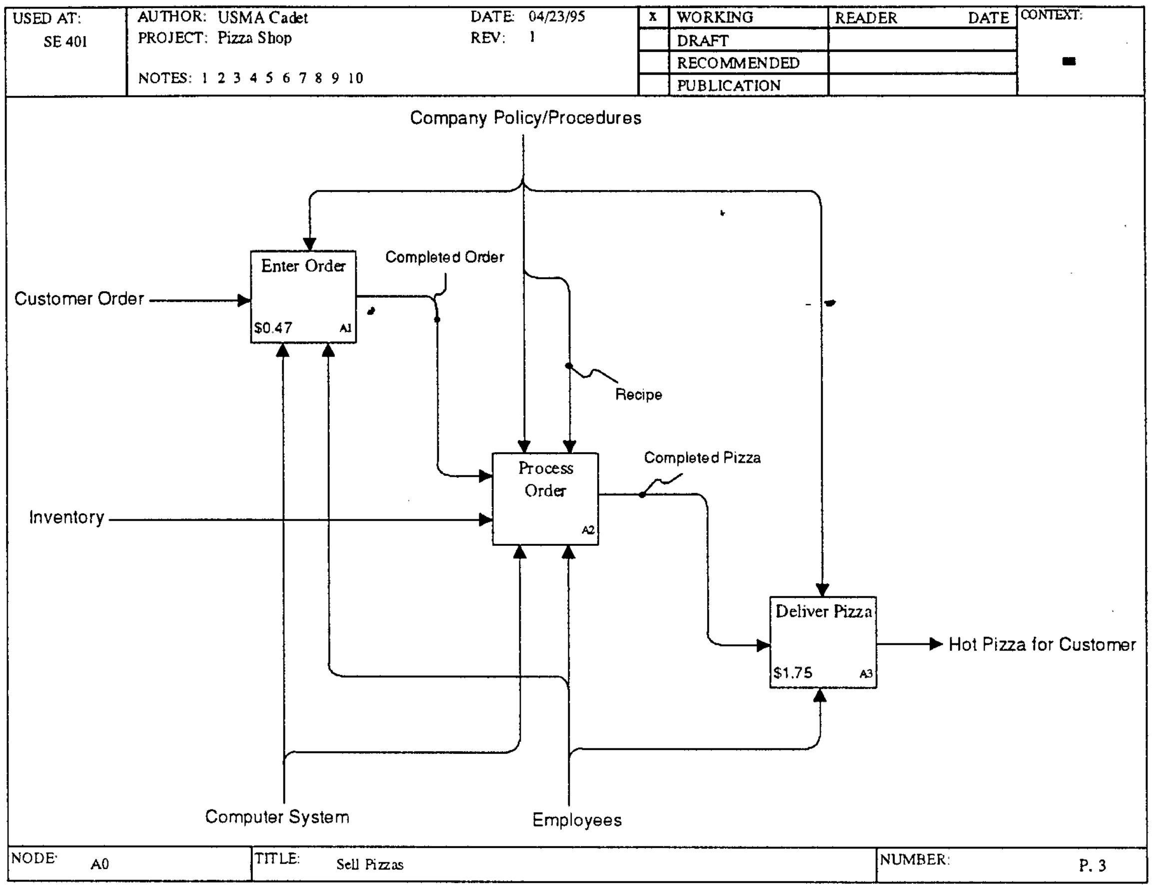
Node Tree for Pizza Problem

[A0] Sell Pizzas
- [A1] Enter Order
- [A2] Process Order
  - [A21] Assemble Pizza
  - [A22] Cook Pizza
  - [A23] Package Pizza
- [A3] Deliver Pizza

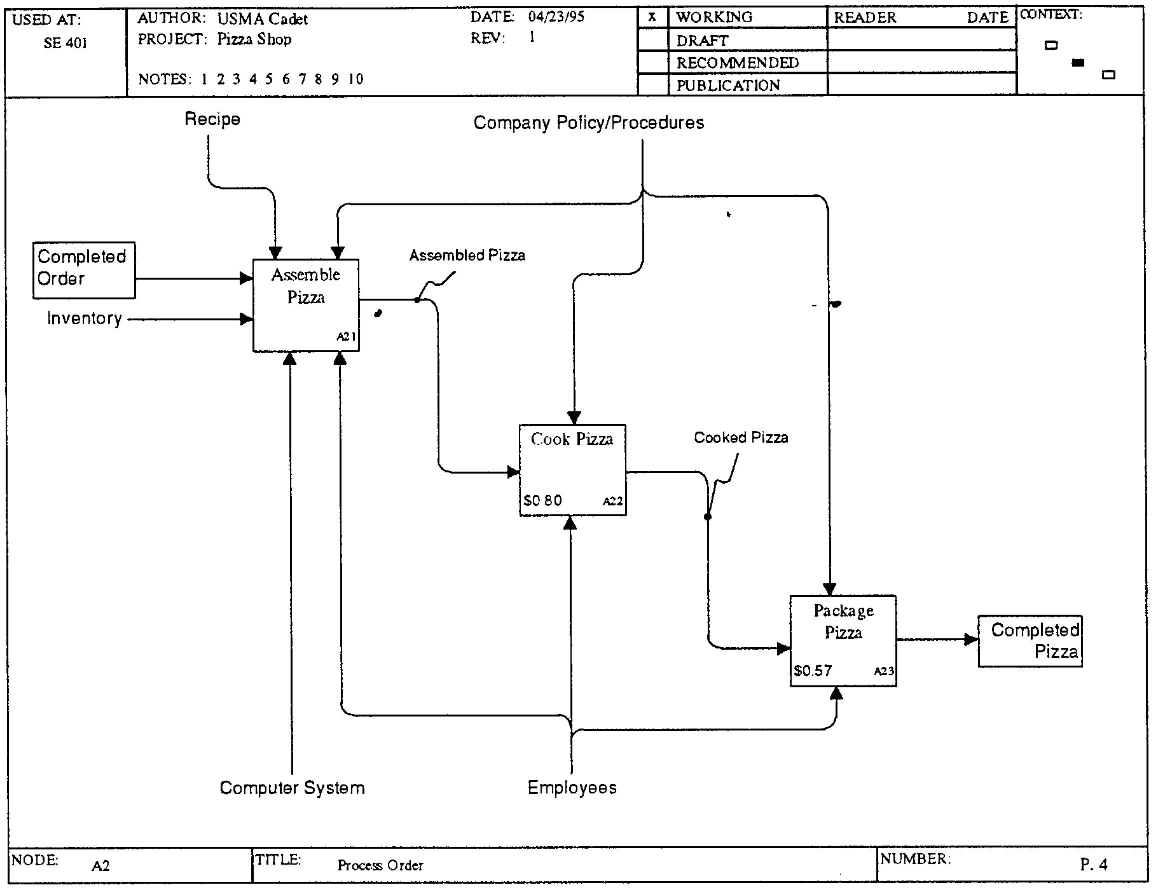


NODE: A-0	TITLE: Sell Pizza	NUMBER: P. 2

Drill Problem #1(continued):



Drill Problem #1 (continued):



Activity Modeling

In the last lesson, you learned about IDEF activity modeling and how it can be used to display the decomposition of a system. These IDEF diagrams are natural starting points for reengineering existing processes. By evaluating the current structure of a system's activities and then asking, "How would I accomplish these objectives if I were designing the system from scratch?", the analyst can compare the *as-is* and the *to-be* models and identify areas where there are significant opportunities for process improvement.

Activity Based Costing

Activity based costing (ABC) is one method that you can use to help determine the relative value added by each activity in a system. It is a technique that measures the cost and performance of activities. [1] This allows the analyst to identify activities that add little or no value to the system, and in turn to consider eliminating or reengineering the processes of which these activities are part.

The goal of ABC is to pinpoint where resources are being expended in a system and to identify what is being gained through these expenditures. A typical system has many activities, and each activity requires some type of resource(s) such as computer time, money, material, manpower, or machinery. The first step of ABC is to determine the cost of each activity. This is typically done by examining historical financial records, talking to the people involved in the process, and sometimes by actually observing the activity while it is being performed. Costs are usually expressed in dollars per unit of output for an activity. The components which comprise an activity's costs could be broken down in many ways. One method is to classify the costs as: [2]

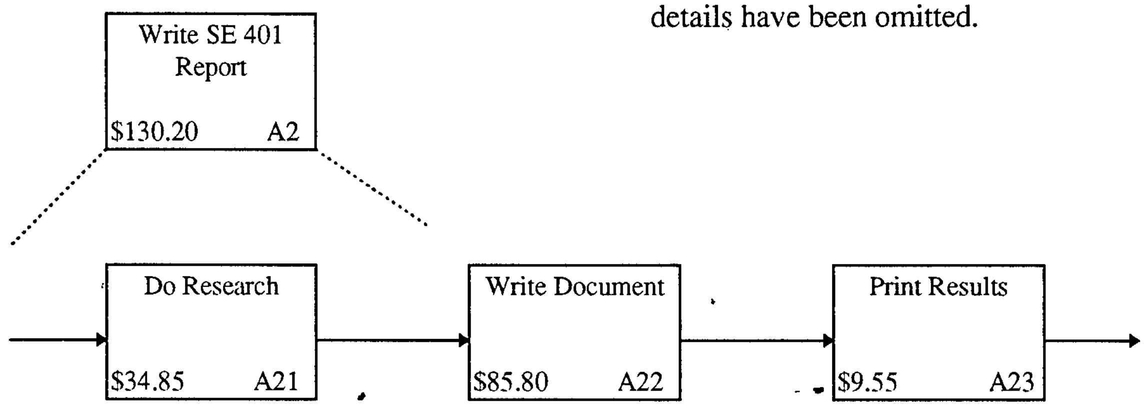
1. Direct Labor: The labor costs for the workers who actually perform the activity. For example, if the activity is "Type Requisition" and a clerk who is

paid \$8.00 per hour takes an average of 15 minutes to type it up, then the direct labor cost is \$2.00.

2. Indirect Labor: A proportional share of all non-direct labor costs that can not be directly associated with specific activities. For example, the labor costs of supervisors, janitors, or security personnel. The "Type Requisition" activity might be allocated \$0.50 in indirect labor costs each time it is performed. Managers and the accounting staff will determine how the overall indirect labor cost will be applied to each activity in the system.
3. Direct Materials or Cost of Goods: The cost of the materials used to perform a specific activity. For example, the "Type Requisition" activity might have a direct material cost of \$0.20 to cover the cost of the form being processed. For a construction activity like "Pour Basement", direct material costs would include the price of the concrete and the steel reinforcement rod.
4. Supplies: The cost of inexpensive, common items used in the performance of an activity. For example, the cost of glue, nails, or paper required by multiple activities are often classified as supply costs.
5. Overhead: A proportional share of all the other system costs. This may include items such as utility costs, taxes, depreciation, repairs, and insurance. Like indirect labor, a certain proportion of the overall overhead cost will be allocated to each activity.

The IDEF model makes the calculation of activity costs easy. The costs for the lowest level activities are calculated first, using the criteria listed above. These costs are then "rolled-up" to determine the cost of the next higher level activity of which they are sub-components. Suppose, for example, our activity is *Write SE 401 Report.* The necessary sub-activities are *Do Research, Write Document,* and *Print Results*, which have activity costs of \$34.85, \$85.80, and \$9.55 respectively. Then the activity cost for *Assemble Student Handouts* is \$130.20, the sum of the three sub-activity costs. Note that the costs are typically recorded in the lower left corner of each activity box.

Note: For the sake of clarity, most IDEF details have been omitted.



Once all the ABC costs have been determined, you can focus in on reengineering opportunities. The key is to identify activities that cost a lot, yet have little or no value-added. Starting at the top of the IDEF model, ask "Which activities could be eliminated or reduced without causing any deterioration to the product or service that the system is designed to provide?" Or, equivalently, we could ask, "Which activities in the model do not support any of our system objectives?" In particular, focus on activities that have relatively high costs. The non-value adding activities identified through this process are typically those which have been added to the system due to non-conformance to standards or policies, or ones that have been used to correct some form of system deficiency. Non-value adding activities lead to non-value adding costs. They waste time, money, and other system resources. They also unnecessarily complicate the overall system.

An activity's "value-added" is the difference between the value associated with that activity's output and the sum of the values of the input, controls and mechanisms that feed into it. As an equation:

$$V_i = O_i - [I_i + C_i + M_i]$$

where:

V_i is the value-added for activity i

O_i is the value of the output of activity i

I_i is the value of the inputs coming into activity i

C_i is the value of the activity's controls

M_i is the value of the mechanisms that are used by the activity.

One way to quantify the value of the input, controls, and mechanisms of an activity is to determine what they cost per unit of output for that activity. For example, say that a particular cadet assesses the value of a finished SE 401 report at $150. (That figure is *obviously* too low, but it will illustrate the point.) If we have determined that the value of the report before it is printed is $140 and that the cost of the controls and mechanisms required to "Print Results" are $1.10 and $8.45 respectively, then the value added for "Print Results" is:

$$V_{\text{Print Report}} = \$150 - [\$140 + \$1.10 + \$8.45]$$
$$= \$0.45$$

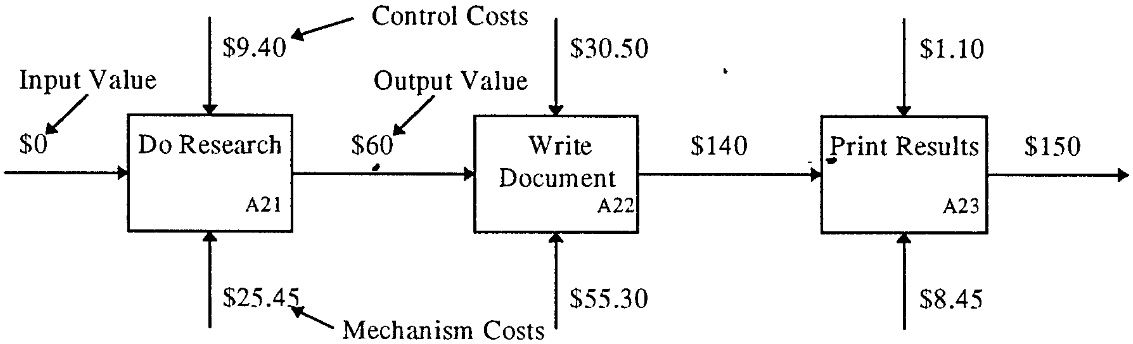
We would conclude that the "Print Report" activity adds $0.45 in value to the process.

We should note at this point that determining the input and output values for each activity is usually not an easy thing to do. It is hard to quantify what the output value of the "Do Research" activity is when we are writing an SE 401 report. One way to approach this is by first determining the value of the final system output (what a typical customer would be willing to pay), and then examining each activity in an attempt to determine how much it contributes to that final value. This is best done by working closely with people who have a very good understanding of the process, allowing them to determine the relative importance of the individual activities. Some iteration and adjustment will usually be necessary, since the value of an activity will be assessed differently by people with varying perspectives on the system.

If, for example, we have come to a consensus among SE 401 students that the final value of a completed SE 401 report is $150, we might assign the costs in proportion to the amount of effort required by each of the sub-activities and come up with $60 as the value of "Do Research", $80 as the value of "Write Document", and $10 as the value of "Print Results". As shown below, we can apply the value-added equation to these figures and determine how much value each of the activities add to the process. Note that whenever the combined input, control, and mechanism costs for an activity are greater than the

output value, we will have a *negative* value-added for that activity. Put simply, the activity is costing more than its output is worth, and such activities are ideal candidates for elimination or modification.

Suppose that the costs and input/output values are:



Then to calculate the value-added for activity A21 we have:

$$
\begin{aligned}
V_{A21} &= O_{A21} - [I_{A21} + C_{A21} + M_{A21}] \\
&= \$60 - [\ \$0 + \$9.40 + \$25.41\ ] \\
&= \$60 - \$34.85 \\
&= \$25.15
\end{aligned}
$$

We are now ready to search for activities which could be improved through reengineering. To do this, we want to identify costs and values that are "out of line" by creating a table which compares the relative proportion of cost and value-added associated with each activity. Be careful to only compare activities that are on the *same level* of the IDEF diagram. For example, it is appropriate to compare the costs of the A1, A2, and A3 activities, but it is incorrect to compare costs associated with the A1 and A22 activities because the A22 activity is at a lower level in the IDEF decomposition than A1. A table that compares the costs of the activities associated with "Write SE 401 Report" might look like:

Activities	Direct Labor	Indirect Labor	Direct Material	Supplies	Overhead	Total Activity Cost	Activity Percentage
Do Research	$22.65	$9.00	$1.75	$0.35	$1.10	$34.85	27%
Write Document	$72.50	$7.00	$3.30	$1.20	$1.80	$85.80	66%
Print Results	$2.40	$0.00	$5.10	$1.45	$0.60	$9.55	7%
			Total Cost of "Write SE 401 Report":			$130.20	

Pareto Cost Analysis

The important thing to examine is the relative costs of the three activities. This is often called a Pareto Analysis[1] because we are trying to identify the 20 percent of the activities that are causing 80% of our costs. In this case, 66% of the student's cost originates from the "Write Document" activity. This activity, therefore, is a logical place to begin looking for ways to improve the "Write SE 401 Report" process.

Once the high-cost areas have been identified and prioritized, we look next at the value added by each of the activities. In tabular form we might have:

Activities	Input Value	Output Value	Control Costs	Mechanism Costs	Value Added	Percent of Positive Value Added
Do Research	$0.00	$60.00	$9.40	$25.45	$25.15	98.24%
Write Document	$60.00	$140.00	$30.50	$50.30	($0.80)	0.00%
Print Results	$140.00	$150.00	$1.10	$8.45	$0.45	1.76%

Value-Added Analysis

So based on these figures, the vast majority of the value is added in the "Do Research" step. The "Write Document" activity, on the other hand, has a *negative* value-added, indicating that the benefit of "Write Document" is less than the costs incurred by performing the activity.

Finally, we compare the cost and value-added of the activities.

---

[1] French economist Vilfredo Pareto studied the distribution of wealth in the 19th century. He observed that a large proportion of overall wealth is consistently owned by a small proportion of society. Since then, this *Pareto Effect* has since been recognized in many different systems where a large percentage of the system resources are consumed by relatively small percentage of the components.

Activities	Activity Cost	Value Added	Activity's Percentage of Total Cost	Activity's Percent of Positive Value Added
Do Research	$34.85	$25.15	27%	98.24%
Write Document	$85.80	($0.80)	66%	negative
Print Results	$9.55	$0.45	7%	1.76%

Comparison of Activity Costs and Value-Added

We look for activities that have a relatively high cost and low value-added. In this example, we see that although 66% of our costs are incurred in the "Write Document" step, it actually has negative value-added. This makes it our number one priority for reengineering. We could ask, for example, why the direct labor costs associated with "Write Document" are so high. Is it because the requirements for the report were not clear? Or, perhaps it took longer than necessary to write the document because the cadet was trying to write the paper at Grant Hall. We could then seek other possible solutions. For example, could a small investment in additional research significantly reduce the direct labor cost associated with writing the document? Are there other steps we could take to make the "Write Document" activity less time intensive?

In summary, we can generally categorize the process of ABC analysis into five steps. First, decompose the activities down to a level where you can pinpoint the specific costs of all activities. Second, starting at the bottom, "roll-up" the costs, aggregating the costs for each decomposition up to the next higher level. Third, determine the input and output values for each activity in the process. From this, calculate the value-added for each activity. Fourth, create tables which allow comparison of the activity costs and value-added for all the activities at a particular level in the decomposition. Identify the activities that have the highest costs. Fifth, and most importantly, prioritize for reengineering those activities that have both high costs and low value-added and seek creative means of reducing costs and adding values.

Indicators of Reengineering Opportunities

Activity based costing is just one of several analytic techniques that you can apply to an IDEF model. As you evaluate an existing system model, be aware that there are

other specific indicators that serve as red flags indicating potential reengineering opportunities. These include: [3]

1. Processes that are broken. Situations where the management, employees, or customers involved readily admit that some of the system's objectives are not being achieved.
2. Cases of extensive information exchange, data redundancy, and information rekeying. These are cases where information is being handled inefficiently. This is typically due to an ill-structured organization. For example, when information needed as part of a process must be bounced back and forth between two or more departments, this is an indicator that perhaps the departmental structure is not efficient. In many instances this is due to unnatural boundaries within a system, boundaries that are created when an organizational structure does not facilitate accomplishment of the systems objectives.
3. Inventories or buffers. Inventories and stockpiles of "spare" items are created to help deal with uncertainty in a system. Often, they indicate a process that can not quickly respond to user requirements. By redesigning the process to coordinate supplier and user schedules and requirements, the inventories may be significantly reduced or eliminated entirely.
4. High ratios of checking and control to value-adding. The activities in a system must be focused on accomplishing the system's objectives. Some amount of checking and control will almost always be required in order to ensure the quality of the system output. However, each step that requires inspection, bookkeeping, and paperwork costs time and money. Thus, it is critical that these administrative activities be kept to a minimum, and handled efficiently when required.
5. Rework. Whenever an activity must be repeated because it wasn't done right the first time, that activity consumes valuable system resources (time, money, manpower, material, etc.). Often times rework must be done because system requirements and specifications are either unclear or change over time.

Reengineering should focus on eliminating the confusion and mistakes that lead to excessive rework.

6. Complexity, exceptions, and special cases. The longer a system is in operation, the more complex it tends to become. This is because what starts out as a simple process is typically modified and added to as time goes on. Eventually, the exceptions, contingency plans, and possible alternatives grow to the point where the original process is lost in the background. When this happens, it is usually necessary to simplify the process, possibly dividing it into several smaller streamlined activities.

7. Duplication of activities. When identical or very similar activities are being performed at various points in a system, it may be possible to consolidate some or all of those activities. This has the potential to eliminate duplication of labor, increase the expertise available for that activity, and reduce the amount of overhead required.

Automation

Activity modeling can also assist in the process of coherently automating activities in a system. The IDEF model specifically delineates how information is passed throughout the process. By understanding this flow, analysts can tailor their computer systems to meet the actual information exchange and data processing activities of the system.

Activity models are also used to create business rule models or data models. A data model is a graphical representation of an organization's information and data expressed in terms of entities and relationships. These relationships are also called business rules because they enable or constrain business actions. This set of rules and data modeling techniques is called IDEF1X (pronounced eye-deaf-one-x).

Summary

The IDEF decomposition process is an activity model which provides a detailed picture of how all the activities in a system interact. It facilitates the application of other

tools such as Activity Based Costing. By looking for key indicators in the decomposed processes, the systems engineer can identify reengineering opportunities and can reorganize the activities to more efficiently meet the system's objectives.

NOTES

[1] Corporate Information Management, Process Improvement Methodology for DoD Functional Managers (Fairfax: D. Appleton Company, Inc., 1993) 103.

[2] Ray H. Garrison, Managerial Accounting (Plano: Business Publications, Inc., 1985) 28-29.

[3] Michael Hammer and James Champy, Reengineering the Corporation (New York: Harper Business, 1993) 122-127.

REFERENCES

Marca, David A., and Clement L. McGowan. IDEF0/SADT Business Process and Enterprise Modeling, Eclectic Solutions, San Diego, CA, 1993.

Lesson Title: Modeling and Analysis - Simulation of Activity Models

Lesson Objectives:

1. Understand the usefulness of simulation as a modeling/analysis technique.

2. Understand the progression from static to dynamic system models.

3. Be able to list and describe several simulation techniques, and know the advantages and disadvantages of each.

4. Be able to use the results of a simulation to recommend changes to both static and dynamic system models.

Study Assignment:

Read: Course Notes, pages 3-2 through 3-7.

Drill Problems:

None.

Other Requirements:

None.

SIMULATION OF ACTIVITY MODELS

Introduction to Simulation

This lesson focuses on another powerful analysis technique called simulation. As you have learned in previous courses, simulation is a field of study that seeks to analyze complex interactions in a system by using a computer to model how the system changes over time. In this lesson, we will learn how we can use simulation to assist us in the analysis-of-alternatives step of the systems engineering design process.

Modeling

Before we can understand the role of simulation in the design process, we need to know what it means to "model" a system. Modeling is the process of developing a description of a system that accounts for all of the system's important properties.[1] That is, a model is an abstraction of reality, a simplified description of the elements and interactions that take place in a complex system. The model is designed to provide the analyst with essential information about system it represents.

It is almost always cheaper and faster to work with a model than to directly study the dynamics of a large-scale system. In some cases, such as when we are developing a new, non-existing system, it may actually be impossible to work with a real system. In these instances, the analyst is forced to rely on models in order to perform the analysis. It is very important that the model be properly formulated, used, and interpreted so that the results accurately reflect the characteristics of the real system.

There are two general modeling paradigms: static and dynamic.[2] A static model represents the structure of a system, but does not show how the system changes over time. IDEF0 is one example of a static model that we have already used in this course. A dynamic model, on the other hand, represents both the structure of the system, and that system's behavior over time. Dynamic models are generally much more detailed than

static models because they must incorporate logic concerning exactly what interactions take place within the model and how the system changes over time. We will use simulation as a dynamic modeling tool to investigate these changes in key system variables, particularly during the operational phase of its life-cycle.

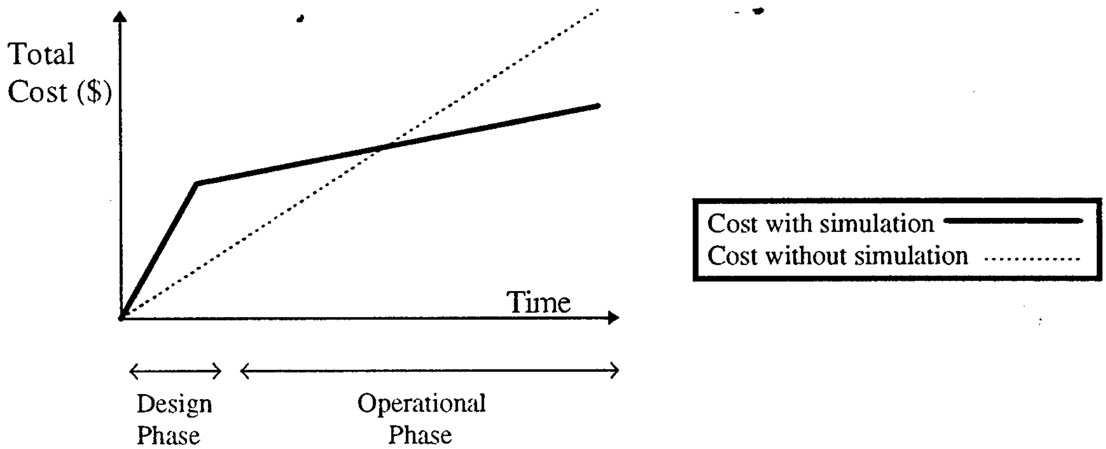
When to Use Simulation

For very simple systems it is sometimes possible to develop *analytic models* which can be solved mathematically.[3] For example, the M/M/1 queuing model, the EOQ inventory model, and simple Poisson Processes are all analytic models you have used in other Systems Engineering courses. To use these types of analytic models, we first verify that the assumptions of the particular model are satisfied, then we determine the required input parameters, and finally we solve for the particular variable(s) of interest. The strength of analytic models is that we can obtain exact solutions. On the other hand, analytic models are usually not sufficient when we are designing large-scale systems. Often, this is because the real-world system fails to satisfy one or more of the assumptions of simple analytic models. Additionally, the larger and more complex a system becomes, the more difficult it is to identify and quantify interacting variables.

Simulation, on the other hand, allows us to develop computer models of complex systems, observe how the system behaves over time, and draw inferences about important system variables. This makes simulation very useful for the types of problems we study in this course. Simulation will not provide exact solutions to a particular problem. It will, however, allow the analyst to statistically analyze results and to make probabilistic statements about the system. For example, we might conduct a simulation of a pizza restaurant and find that at a 95% confidence level, the mean time it takes to make a pepperoni pizza is between 3.5 and 3.7 minutes. We will not obtain exact solutions, but can obtain approximations to the necessary level of precision.

Advantages and Disadvantages of Simulation

Building a simulation of a system usually requires a significant investment of time and effort. The costs include software, training, and time.[4] The benefits, however, include an improved ability to understand the interactions of the system. In the long-run, this leads to the capability to design a more appropriate, efficient, and cost-effective system. The trade-offs will typically look like:



This shows that the additional up-front cost associated with developing a simulation can quickly be recovered through efficiency and cost savings in the operational phase of the systems life-cycle.

Other advantages of simulation discussed by Schmidt and Taylor (1970) include:[5]

1. Once a model is built, it can be used repeatedly to analyze proposed designs or policies.
2. It is usually the case that simulation data is much less costly to obtain than similar data from the real system.
3. Simulation methods are usually easier to apply than analytic methods. Thus, there are many more potential users of simulation methods than of analytic techniques.

4. Whereas analytic models usually require many simplifying assumptions to make them mathematically tractable, simulation models have no such restrictions.
5. In some instances, simulation is the only means of deriving a solution to a problem. That is, simulation can be used in cases where analytic models do not exist.

Schmidt and Taylor also point out that there are several disadvantages to simulation. These include:

1. Simulation models may be costly, requiring large expenditures of time for construction and validation.
2. Simulation is sometimes used even when precise analytic techniques would suffice.
3. Simulation results are only as good as the model used to derive them. That is, if the model fails to capture important aspects of the system, the results may be misleading or incorrect.

Methods of Simulation

There a several techniques that can be used to simulate a system. At the simplest level, a spreadsheet can be used to capture important system dynamics. The spreadsheet can be used to record the values of key system variables, relationships can be established by linking the cells and then the variables can be updated according to formulas that define these relationships. The analysts can then conduct "what-if" scenarios to study how changes in one variable affect other system variables. This type of simulation may be appropriate for simple systems, but it is very difficult to use a spreadsheet to capture how a system changes over time.

When a system is too complex for a spreadsheet simulation, or when changes over time are important, it is usually necessary to employ some type of simulation software

such as ProModel, Service Model, or Power Sim. These are computer programs specifically designed to allow analysts to model system dynamics on a personal computer. The analyst must first use the program to build a model of the system. This involves describing the elements of the system, specifying their important characteristics, defining relationships, and incorporating logic about how entities flow through the system. Once the model is complete, the analyst can execute it and have the computer track the state of key system variables. Typically, multiple iterations are run, and the results allow the analyst to statistically determine important quantities such as the mean, standard deviation, maximum, and minimum for key system variables. The software makes it easy to incorporate minor changes into the model, run the simulation again, and analyze the new results.

There are cases where simulation software is not adequate to model a system. This can happen when a system is very complex, where unpredictable human reactions are expected, or when many of the relationships within the system are difficult to establish. In these cases, it may be necessary to simulate the system by actually constructing a simplified version of the system. For example, automobile companies might build a prototype of a vehicle in order to test how the proposed sub-systems will interact. An infantry company might simulate a movement to contact by having key unit personnel walk through the planned mission. A chemical processing plant might test the design of a new system by creating a small scale model of the equipment involved. Each of these examples are a type of simulation. They add a degree of realism that is difficult to obtain from computer simulations, but do so at the expense of increased cost, increased time, and decreased flexibility.

Notes:

[1] Webster's II New Riverside University Dictionary (Boston: Houghton Mifflin Company, 1994) 761.
[2] Design IDEF Tutorial for Microsoft Windows (Cambridge: Meta Software Corporation, 1995) 2-2.
[3] Jerry Banks and John S. Carlson, II, Discrete-Event System Simulation (Englewood Cliffs: Prentice Hall Inc, 1984)

[4] Charles Harrell and Kerim Tumay, Simulation Made Easy (Norcross: Institute of Industrial Engineers, 1995) 13.
[5] J.W. Schmidt and R. E. Taylor, Simulation and Analysis of Industrial Systems (Homewood: Irwin, 1970)